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AN INVESTIGATION OF THE MEASUREMENT OF STREAMFLOW UNDER WINTER CONDITIONS:

INTERNATIONAL HYDROMETRIC GAUGING STATION ON THE RED RIVER AT EMERSON, MANITOBA, CANADA

Inland Waters and Lands
Western and Northern Region

Eaux intérieures et terres
Région de l'ouest et du nord

Canada

[redacted]

AN INVESTIGATION OF THE MEASUREMENT OF STREAMFLOW UNDER WINTER CONDITIONS:

INTERNATIONAL HYDROMETRIC GAUGING STATION ON THE RED RIVER AT EMERSON, MANITOBA, CANADA

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January 1988

IWD-WNR(W)-WRB-HI-88-1

ABSTRACT

Computed streamflows on the Red River at Drayton in North Dakota, U.S.A., have been generally higher, under winter conditions, than computed streamflows on the Red River at Emerson in Manitoba, Canada. The station at Drayton is located 85 km upstream from Emerson. These differences have been noted through the international joint review and approval of the Red River streamflow record at the Emerson International Gauging Station. Moreover, historically, the U.S. Geological Survey has measured higher streamflows under ice conditions than the Water Survey of Canada on the Red River at Emerson. The difference between their discharge measurements under ice conditions is generally between +10% and 20%.

To explain these differences, field and laboratory experiments were conducted in 1986, which included an international field metering program at Drayton and Emerson; rating of current meters and suspension equipment at national calibration services in Canada and the United States; and testing of current meters in flowing water.

The techniques used by WSC and the USGS for measurements under ice cover were reviewed and no significant differences noted except in the metering equipment. The USGS uses a Vane type meter on rod suspension and WSC, a cup type meter on rod or cable suspension.

Through the analysis of the field and calibration data it was determined that significant differences exist between a current meter rated on rod and on cable suspension and that this suspension effect is responsible for the large differences in measurements between the USGS and WSC.

Small differences in depth measurements were observed between the USGS and WSC, and found to be reducible by change in practices of technicians of both agencies. Differences in current meter rating procedures between the United States and Canada were noted, and found to be small for velocities higher than 0.3 m/s, but to increase rapidly as the velocities decrease below 0.3 m/s. The Vane type meter was found to give consistently higher velocity than the cup type meter, even under controlled conditions, i.e. 1-m flume. The cup type meter, based on limited flume experiments, was found to be more accurate than the Vane type.

Changes in discharge measurement techniques under ice conditions are recommended, including the sampling of vertical velocity curves, and an increased time of exposure for current meter observations. Several investigations are recommended to improve the overall quality of streamflow records for the winter ice period.

RESUME

Généralement, le débit calculé de la rivière Rouge, à Drayton, dans le Dakota du Nord, est supérieur, en hiver, au débit calculé à Emerson, au Manitoba. La station de Drayton se trouve à 85 km en amont d'Emerson. Les écarts ont été observés au moment de l'examen et de l'approbation internationaux des enregistrements du débit de la Rouge, à la station internationale de jaugeage d'Emerson. En outre, les résultats des mesures de l'U.S. Geological Survey (USGS) à Emerson ont toujours été plus élevés, dans les conditions d'englacement, que ceux de la Division des relevés hydrologiques (DRH) du Canada. L'écart, dans ces conditions, est généralement de +10 et de +20 %.

Pour les expliquer, on a entrepris, en 1986, une campagne de mesures sur le terrain et en laboratoire, laquelle comprenait : des mesures sur le terrain, à Drayton et à Emerson, par une équipe internationale; l'étalonnage des moulinets hydrométriques ainsi que de leur système de montage, par les services canadiens et américains compétents; la mise à l'essai des moulinets en eau courante.

L'examen des techniques utilisées par la DRH et l'USGS pour les mesures sous la glace révèle qu'elles ne diffèrent que par l'équipement de mesure. L'USGS utilise un appareil à ailettes fixé à une perche; la DRH, un moulinet à coupelles fixé à une tige ou attaché à un câble.

L'analyse des données d'étalonnage et des données de terrain a révélé des écarts significatifs entre les montages à perche et à câble des deux organismes nationaux et attribuables à ces montages.

On a aussi observé de petits écarts de profondeur entre les méthodes des organismes des deux pays et constaté qu'on pouvait les effacer par la modification des modes opératoires utilisés par les techniciens des deux organismes. On a aussi observé des différences dans les méthodes d'étalonnage et constaté qu'elles étaient petites pour les vitesses supérieures à 0.3 m/s mais qu'elles s'accroissaient rapidement à mesure que la vitesse s'abaissait au-dessous de cette valeur. Le moulinet à ailettes s'est révélé donner des valeurs de vitesse constamment plus élevées que le type à coupelles, même dans des conditions normalisées, c'est-à-dire dans un canal de 1 m. Le type à coupelles s'est révélé, à la lumière d'un nombre limité d'expériences en canal, plus fidèle que le type à ailettes.

Il est donc recommandé de modifier les techniques de mesure du débit sous la glace, y compris d'établir plusieurs courbes de vitesse dans le sens vertical et d'augmenter la durée des observations. Plusieurs études sont recommandées pour améliorer la qualité générale des enregistrements du débit en hiver.

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METRIC - IMPERIAL UNITS EQUIVALENCE

Metric Units		Multiplier	Imperial Units
	Symbol		Symbol
Description	Multiply	By	To obtain
metre	m	3.280 8	ft
centimetre	cm	0.393 70	in.
millimetre	mm	0.039 37	in.
kilometre	km	0.621 37	mi
square kilometre	km^2	0.386 10	mi^2
cubic metre per second	cms	35.315	cfs
metre per second	m/s	3.280 8	ft/s

GLOSSARY

WSC: Water Survey of Canada

USGS: U.S. Geological Survey, USGS crew measuring with USGS Vane ice meter I-39

WSC1: WSC crew measuring with WSC winter meter 6-356 on rod suspension

WSC2: WSC crew measuring with WSC winter meter 6-388 on rod and cable suspension

HIF: Hydrologic Instrumentation Facility, where current meters are calibrated in the United States

CCIW: Canada Centre for Inland Waters, where current meters are calibrated in Canada

ACC: Average correction coefficient, computed as the ratio between Emerson and Drayton monthly mean flow, if ACC is greater than 1.0, it indicates that Emerson monthly mean flow is higher that Drayton flow

SD: Standard deviation

MAX: Maximum

MIN: Minimum

NV: Number of verticals taken in the cross section

V: Velocity

N: Number of revolutions per second

R_i: Parameter ratio, computed as USGS measured parameter divided by WSC measured parameter. The measured parameter may be area, mean velocity or discharge.

DD: Difference in depth (USGS-WSC)

V.2d: Velocity at 0.2 of the total depth from the surface

V.8d: Velocity at 0.8 of the total depth from the surface

CC: Correction coefficient required to convert rigid rod rating to cable rating

PSD: Percentage standard deviation or coefficient of variation, equal to twice the standard deviation divided by the mean, expressed in percentage.

ACKNOWLEDGMENTS

The author gratefully acknowledges the assistance and cooperation received during the development of this study from Gerald L. Ryan, Hydrologist, U.S. Geological Survey, Grand Forks, North Dakota District; Kelvin L. Boespflug and Wayne R. Westensee, U.S. Geological Survey, and Steve A. Lokits, Anthony T. Carpenter, and Clare Bowden, Water Survey of Canada, for the field data collection on the Red River at Drayton and at Emerson, respectively; Craig C. Handkamer, Water Survey of Canada, for the drawings; C. Neil DeZeeuw, P. Engel, Clarence Bil, and Brian C. Trapp, National Water Research Institute, for the calibration of the current meters in still and flowing waters; and William R. Kaehrle for the calibration of meters at the U.S. Geological Survey Calibration Services.

The writer wishes to thank J.G. Way, D.G. Hanson, I.S. McLaurin, K. Wiebe, P. Engel, G.L. Ryan, and J. Andrews for their suggestions on the manuscript.

1. INTRODUCTION

The stream gauging station on the Red River at Emerson, Manitoba, was established in 1912 by the Manitoba Hydrographic Survey, and has been classified as an International Gauging Station since 1930. The Manitoba Water Resources Branch (MWRB) uses the data for flood forecasting and operation. The city of Winnipeg, Water Quality Branch of Inland Waters and Lands, MWRB, and U.S. Environmental Protection Agency (U.S. EPA), all receive data on a monthly basis. In fact, data from this station are supplied to users more frequently than from any other in Manitoba.

The International Gauging Station on the Red River at Emerson, Manitoba, is currently operated by Water Survey of Canada in cooperation with the U.S. Geological Survey. Water Survey of Canada is responsible for the operation and maintenance of the gauging station. The station is visited at regular intervals by WSC field staff and at least three times a year by USGS field staff. Streamflow records are computed by Water Survey of Canada, and then jointly reviewed and approved by both agencies prior to publication.

During the joint approval process of the streamflow records for the winter period at Emerson, differences were noted. Usually, the U.S. Geological Survey measures higher streamflows than Water Survey of Canada at Emerson. In the past, compromises were necessary for the published data.

In January 1979, an international metering program was conducted on the Red River at Emerson by both organizations. Although large differences between measured discharges by both agencies were observed, the causes of these differences were not identified. Based on the field investigation, a draft report was prepared by Sawatzky (1979).

In 1985, an investigation into the measurement of streamflow under winter conditions on the Red River at Emerson was requested by Mr. G. Hanson, Area Engineer, Water Survey of Canada. This report presents the results of the investigation. Another study will investigate the open water period.

First, the hydrology of the Red River basin is described and an outline is given of the current hydrometric practices used by the U.S. Geological Survey and Water Survey of Canada, including the procedures for the operation of an International Gauging Station. The definition of the problem and the methodology employed are then explained.

The field data collected on the Red River at Drayton, North Dakota, and at Emerson, Manitoba, during the international metering program in January 1986 are presented and summarized. Also presented are the data collected in laboratory during the testing of the metering equipment in still and flowing water.

The data collected in the field and in the laboratory are then analyzed. Several effects are thoroughly investigated, including the effect of depth soundings; suspension; current meter rating procedures; current meter design; limited number of observations in the vertical; and limited time of exposure. Based on the data analysis, conclusions are drawn and recommendations made for the measurement of streamflow under winter conditions.

2. BACKGROUND INFORMATION

The hydrology of the study area is briefly described in Section 2.1. The procedure for operating and maintaining an International Gauging Station is outlined in Section 2.2. The hydrometric principles and practices followed by the USGS and WSC for discharge measurements under ice cover are described in Section 2.3. The definition of the problem and the methodology followed for the investigation are then presented in Sections 2.4 and 2.5, respectively.

2.1 Red River Basin

The hydrology of the Red River basin is complex because of the basin's size, shape, sub-basin variability, and extreme variation in seasons.[1] The basin (Fig. 1) is located near the geographical centre of North America. The river drains parts of the Canadian provinces of Manitoba and Saskatchewan, and parts of the states of North Dakota, Minnesota, and South Dakota. It is joined by the Assiniboine River from the west and flows into Lake Winnipeg.

The area is characterized as glaciated plain with moraines, lakes, and lacustrine plains.

The mouth of the Red River is at Lake Winnipeg in Manitoba. Lake Winnipeg is about 400 km (250 mi) long and drains from its northern end through the Nelson River northeastward to Hudson Bay. Because of the Red River's sinuosity (large number of meanders), the channel length of the river is nearly double the length of the direct line from source to mouth.

The Red River at the international boundary drains a total of 103 780 km^2 (40 070 mi^2) and of this area, 5180 km^2 (2000 mi^2) is in the upper Pembina River basin in Canada. Also, about 2930 km^2 (1130 mi^2) of the total area in northwestern Minnesota is drained by the Roseau River, which joins the Red River north of the international boundary.

2.2 Operation of International Gauging Stations[2]

As a general rule, the location of the gauging station shelter housing the water level recorder will determine whether a station will be operated by a Canadian or United States agency. Normally, the operating agency will be the one in whose country the principal gauging structure is located. Where possible, the appropriate officers of both agencies should arrange for a minimum of three visits annually to each International Gauging Station by field officers from the agency of the other country.

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[1] The hydrologic description presented is taken from Miller and Frink (1984).

[2] The information presented is taken from the "Procedural Guide for International Gauging Stations on Boundary Waters between Canada and the United States of America" (Huberman *et al.*, 1985).

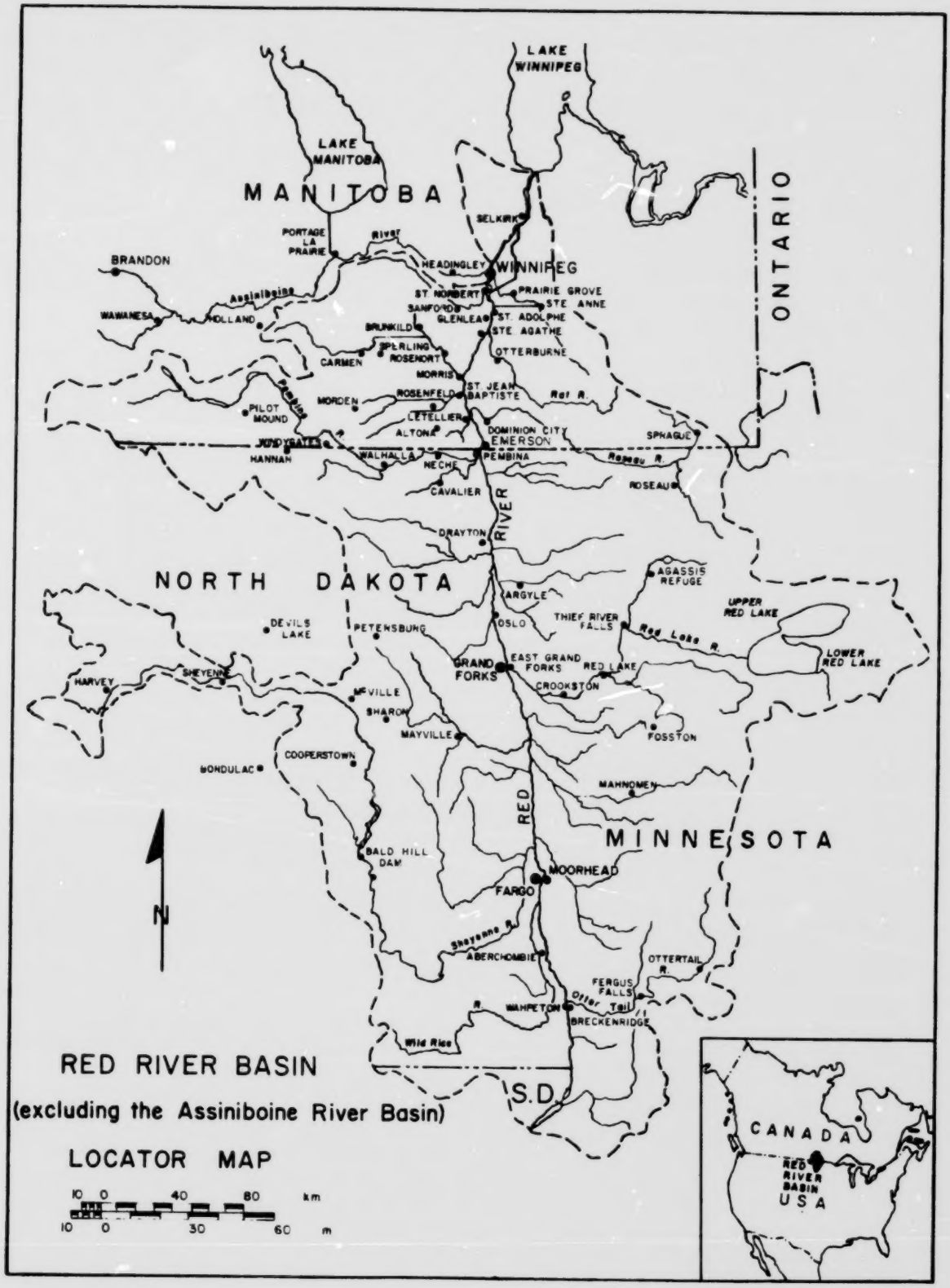

Figure 1. Red River basin.

The field work performed by a field officer at an International Gauging Station may follow the prescribed routine procedure customarily used in the country of the visiting officer. Streamflow measurements should be made on each visit by field officers of either agency unless conditions or other commitments preclude such measurements. The verified original notes for any level check on flow measurement at an International Gauging Station shall be forwarded to the District or Regional office responsible for the computation of the station record.

In general, it is desirable that each District or Regional office complete the initial office computation of the records for each International Gauging Station in its District or Region in accordance with the standard procedure established for its regular stations, making appropriate use of the data provided by the other office involved in the field activities at the station. Original office computations may be made by using comparison data available from hydrologically compatible stations located on either side of the border.

After completion of the initial computations, joint review and approval of records shall be made by the two appropriate field representatives, who are the District and Regional Chiefs or by their designated field officers.

Personnel of the office verifying the initial data computations of the originating office are entitled to verify all steps in the computation procedure, including comparison with hydrologically compatible stations on either side of the border. Given the different computational methodology of both countries, mutual agreement must be reached on calculated figures and estimated discharge figures for the winter ice-period or other backwater periods, as well as for the final listing of data which is to appear in the annual surface water data publications.

After completion of the joint review of records either by visit or by correspondence, the District and Regional Chiefs, or their designated field officers, shall give their joint approval to the record computations and affix their signatures to the final listing of the data to be published.

Following the joint review and approval, copies of the records for an International Gauging Station will be provided to the appropriate District or Regional office in the other country for inclusion in its manuscript for publication.

2.3 Current Hydrometric Procedures

2.3.1 USGS Field Procedure for Measurements under Ice Cover[3]

After a favourable cross section is selected, at least 20 holes are cut for the current meter measurement of discharge. The holes should be spaced so that no subsection carries more than 10% of the total discharge.

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[3]The material presented is taken from Corbett et al. (1957), Buchanan and Somers (1980), and Rantz et al. (1982).

The effective depth of the water (Fig. 2) is the total depth of water minus the distance from the water surface to the bottom of the ice. The vertical pulsation of water in the holes in the ice sometimes causes difficulty in determining the depths. The total depth of water is usually measured with an ice rod or with a sounding weight and reel, depending on the depth. The distance from the water surface to the bottom of the ice is measured with an ice-measuring stick.

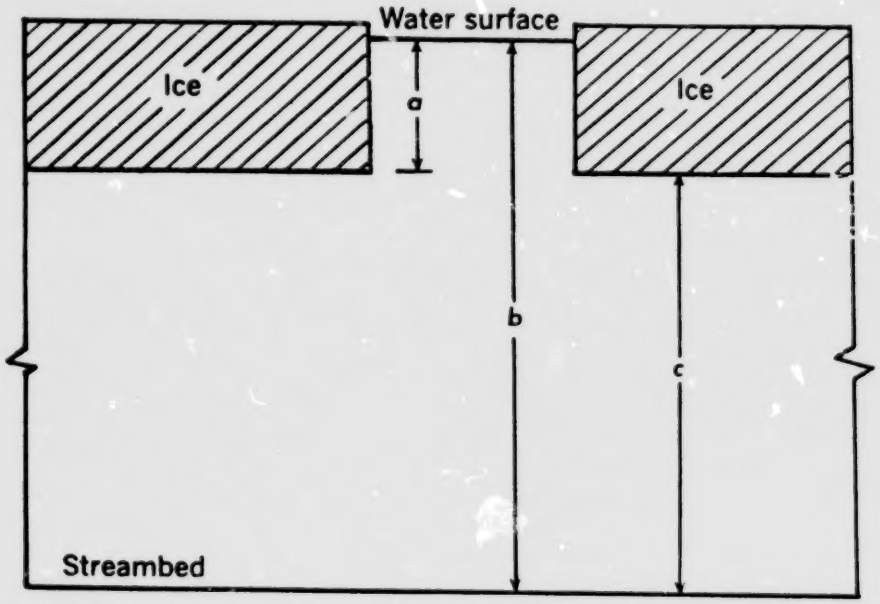

Figure 2. Method of computing meter settings for measurements under ice cover (after Rantz et al., 1982).

The Vane ice meter (Fig. 3) is recommended for use under ice cover because (1) the vanes do not become filled with slush ice as often in the case of the Price meter, (2) the yoke of the Vane meter will fit in the hole (152 mm, or 6 in.) made by the ice drill, and (3) the yoke and ice rod can serve as an ice-measuring stick. The contact chamber of the Vane meter can be rotated to any position; its binding post is therefore placed perpendicular to the axis of the yoke as the horizontal leg of an ice-measuring stick.

In making a discharge measurement, the 0.2 and 0.8 depth method is recommended for effective depths equal to or greater than 2.5 ft (0.762 m) and the 0.6 depth method for effective depths less than 2.5 ft (0.762 m). It is also recommended that two vertical-velocity curves be defined when ice measurements are made to determine whether any coefficients are necessary to convert the velocity obtained by the 0.2 and 0.8 depth method, or by the 0.6 depth method, to the mean velocity. Normally, the average of the velocities obtained by the 0.2 and 0.8 depth method gives the mean velocity, but a coefficient of about 0.92 usually is applicable to the velocity obtained by the 0.6 depth method.

The Vane meter has the principal disadvantage of not responding as well as the Price type AA current meter at low velocities, i.e. less than 0.5 ft/s (0.15 m/s) (Rantz et al., 1982). The operation is identical with that of a Price meter, the major difference being that it is equipped with vanes (4) rather than bucket-type wheels (6).

Schneider and Futrell II (1984) studied the Vane ice meter and concluded that the meter should be used only for velocities greater than 0.15 m/s (0.5 ft/s). They also recommended that the Vane meter be used only on a rod.

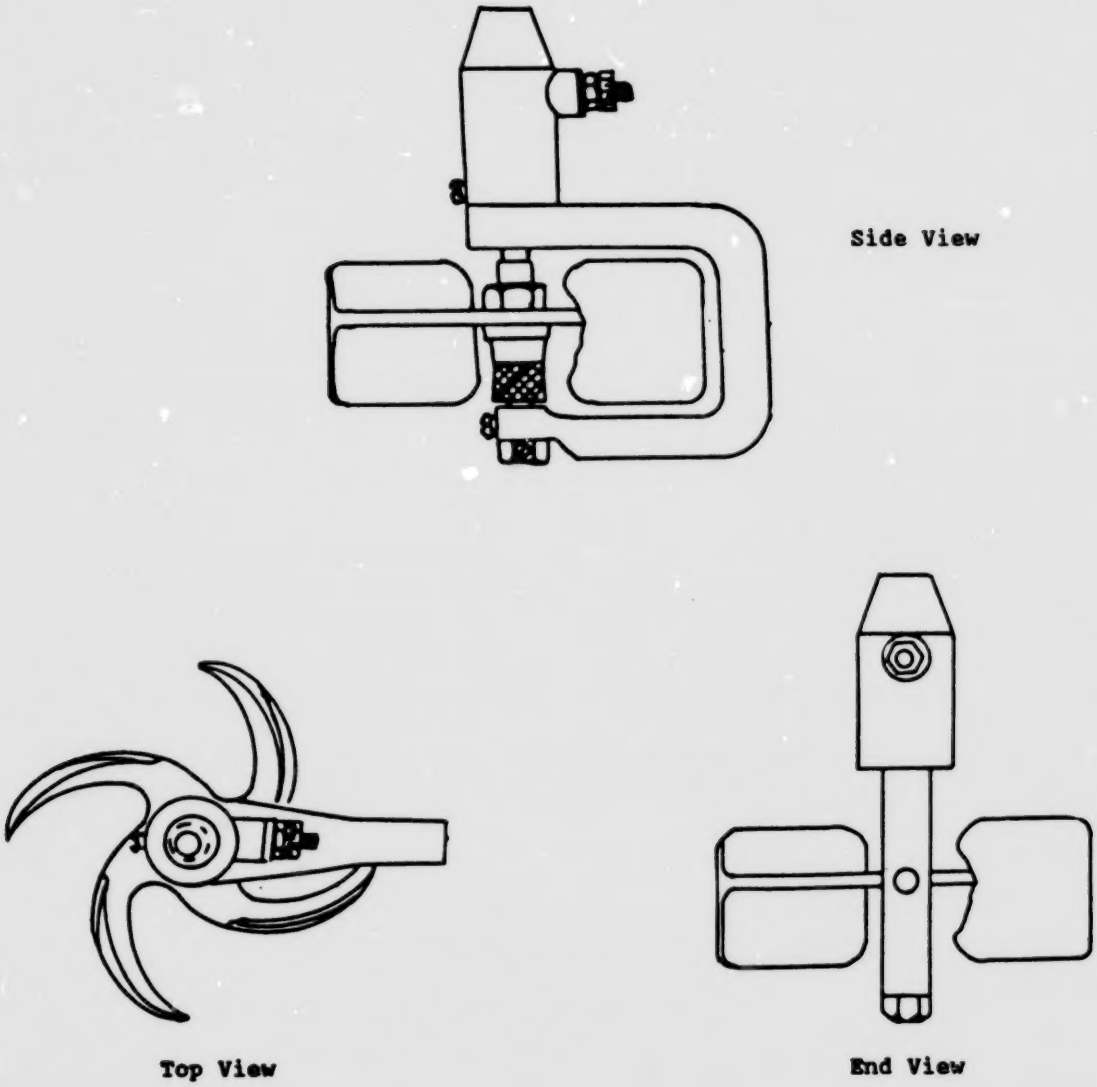

Figure 3. Current meter, Vane type (after Schneider and Futrell II, 1984)

2.3.2 WSC Field Procedure for Measurements under Ice Cover[4]

There should be a minimum of 20 to 25 observation verticals in the cross section. The holes across the metering section should be distributed so that the discharge measured in any one panel is no greater than approximately 5% of the total.

The WSC winter meter (Fig. 4) is recommended for use under ice cover. The meter is calibrated only on a rigid rod. Discharge measurements through ice cover can be made using various equipment assemblies (Fig. 5). The most commonly used are the winter rod set , "A" reel and tripod, and the winter metering sled. Hand lines have been used at locations where access to a station is difficult and the depths at the metering section are too great for the winter rod set. In fact, hand lines are used extensively in northern Canada. Various sounding weights (Figs. 6, 7 and 8) that can pass through the 8-in. (203 mm) holes cut with the ice auger are available for use with either the tripod, the metering sled or the hand line.

For measurements from ice cover it is necessary to determine the effective depth, that is, the distance between the bottom of the ice surface or slush ice pack and the bottom of the stream. If using the winter rod set, the 0.2 and 0.8 depth method is recommended where the effective depths are 0.75 m (2.46 ft) or greater and the 0.5 depth method for depth less than 0.75 m (2.46 ft). If a winter weight assembly is used, the 0.2 and 0.8 depth method can only be used where effective depths are equal to or greater than 1.3 m (4.27 ft), since the meter is 0.24 m (0.79 ft) above the bottom of the weight.

The shapes of vertical velocity curves for water flowing under ice cover differ from those of water flowing in an open channel. Even though these differences exist and provided that the depths are sufficient, the 0.2 and 0.8 depth method can be used for velocity observations. Where depths are insufficient for this method, the 0.5 depth method with an assumed coefficient of 0.88 or the 0.6 depth method with an assumed coefficient of 0.92, must be used.

With the exception of the yoke design, the WSC winter meter is in every respect identical with the Price No. 622 type AA meter. The overall distance from the front of the bucket wheel to the back of the yoke is 15.2 cm (6 in.). This permits the use of the 20.3-cm (8 in.) diameter ice drill cutter head to drill the required holes in the ice cover of a river cross section.

The yoke was designed primarily to allow the meter to be used with the winter rod set. The meter is attached to the bottom section of rod by way of the threaded boss located on the upper limb of the yoke. A winter rod base or foot is available for use with the winter rod set. When taking soundings, the base protects the meter by preventing contacts with bed materials. Also, a horizontal projection at the top of the rod base protects the meter from damage when it is raised through the ice cover. Should it be necessary to use the meter with one of the winter weight assemblies, a brass adapter must be attached to the boss in order to allow the meter to be fitted in the frame of a winter weight hanger. The meter and weight assembly can then be suspended by hand line, or a coaxial cable and sounding reel can be used.

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[4]The material presented is taken from Terzi (1981).

Schneider and Futrell II (1984) studied the WSC winter meter and concluded that the meter should be used only for velocities greater than 0.076 m/s (0.25 ft/s).

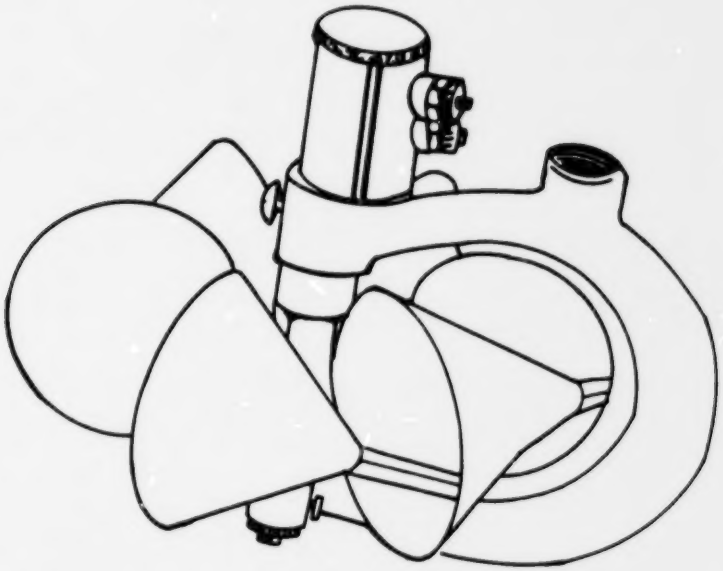
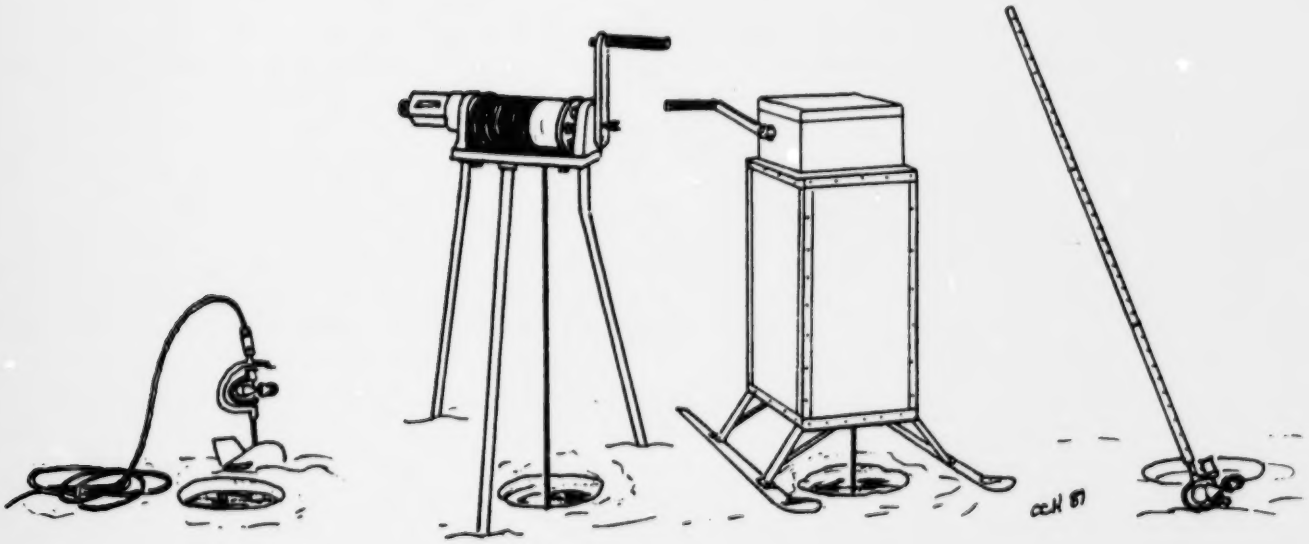


Figure 4. WSC winter meter, cup type (after Schneider and Futrell II, 1984).



hand line | "A" reel and tripod | winter metering sled | winter rod set

Figure 5. Suspension equipment (WSC).

The NACA weight (also known as "tear drop" or Winnipeg) assembly is shown in Figure 6. The upper part of the hanger bar is semicircular and offers some protection to the meter when the assembly is being lowered and raised through ice cover. The 18-lb (8.2 kg) sounding weight is made of lead.

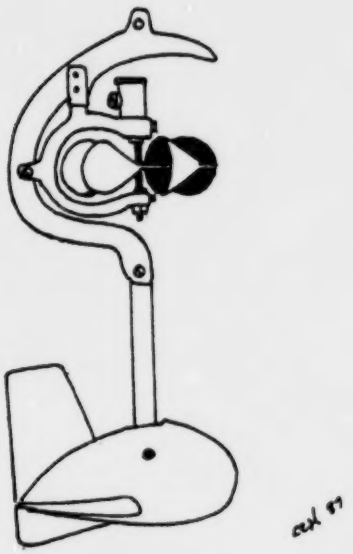


Figure 6. Winter weight assembly (NACA, Winnipeg or "tear drop").

The Pancake winter weight assembly is another type of assembly used to hold the winter current meter. Cast in one piece, this assembly weighs 35 lb (15.9 kg).

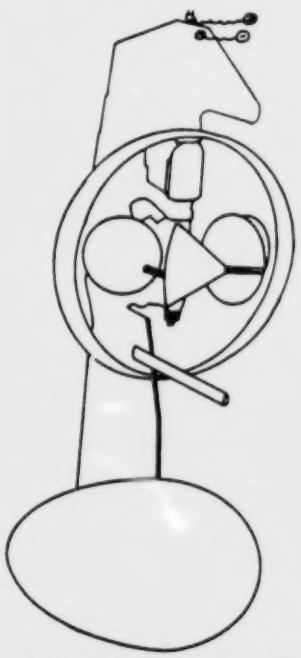


Figure 7. Pancake winter weight assembly (after Schneider and Futrell II, 1984).

The Slush-n-all winter weight assembly is also used by Water Survey of Canada. The weight used is modified elliptical and the U-shaped suspension allows it to assume a vertical position (nose up) when the assembly is being lowered or raised through slush or ice. The force of the water on the tail fins when the weight is below the ice or slush surface brings the weight to a horizontal position.

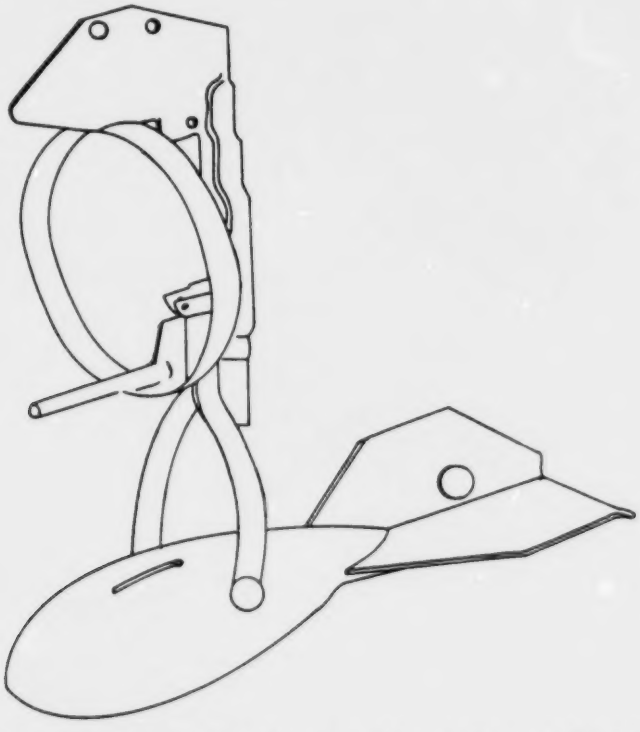
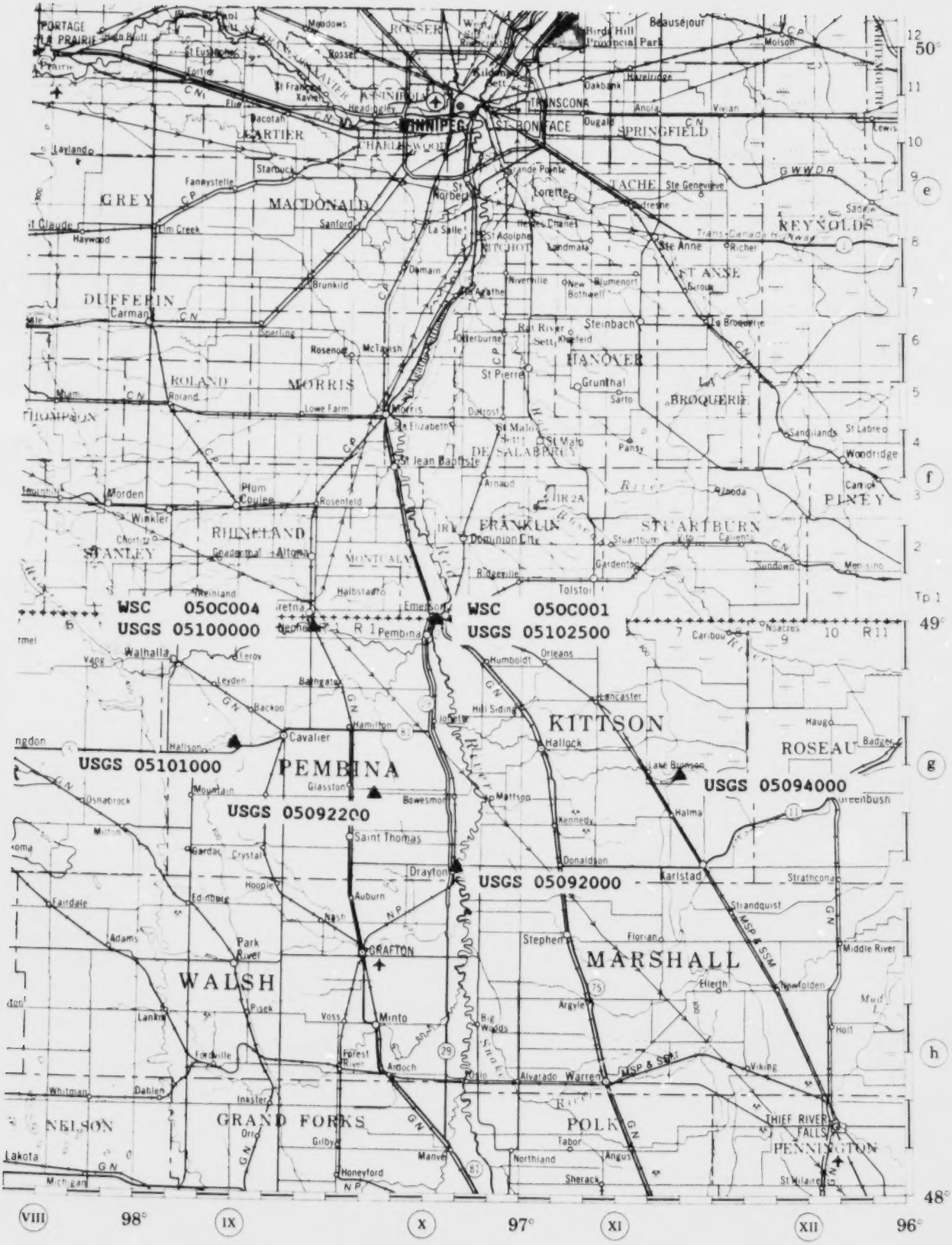


Figure 8. Slush-n-all winter weight assembly (after Schneider and Futrell II, 1984).

2.4 Definition of the Problem

A difference in flow values measured at Drayton, North Dakota, and Emerson, Manitoba, has been observed. This report will deal exclusively with the difference in flow values between Drayton and Emerson during the winter period (ice cover). A subsequent report will address the problem of differences during the open water period.

The streamflow station on the Red River at Emerson, Manitoba, is located 1.2 km (0.7 mi) downstream from the International Boundary (U.S.A. - Canada). Upstream from Emerson, the Red River is gauged at Drayton, North Dakota, by the U.S. Geological Survey (station 05092000). The station is located 84.4 km (52.4 mi) upstream from Emerson. Drainage areas for the stations at Emerson and Drayton are, respectively, 104 000 km^2 (40 200 mi^2) and 90 100 km^2 (34 800 mi^2). Within the Drayton to Emerson reach several tributaries enter the Red River. Almost all of the tributaries within the reach are gauged by the U.S. Geological Survey. These gauged tributaries are Pembina County Drain 20, Tongue River, South Branch Two Rivers, and Pembina River. A map showing the location of the streamflow stations is presented in Figure 9.


WSC 050C004
USGS 05100000
WSC 050C001
USGS 05102500
USGS 05101000
USGS 05092200
USGS 05092000
USGS 05094000
PEMBINA
KITTSON
MARSHALL
WALSH
GRAND FORKS
POLK
PENNINGTON
ROSEAU
RENVILLE
MOUNTRAIL
WARD
WINNIPEG
GRAFTON
DUFFERIN
MORRIS
HANOVER
ST ANNE
KEYNOLDS
RHINELAND
STANLEY
FRANKLIN
ST ARTBURN
PINEY
LA BROQUERIE
MACDONALD
GREY
ROLAND
THOMPSON
DE SALABERRY
ST BONIFACE
TRANSCONA
SPRINGFIELD
ROSSER
PORTAGE LA PRAIRIE
Bausejour
Birds Hill Provincial Park
Molson
Oakbank
Anola
Vivian
Lewis
Dugald
Ste Genevieve
Richer
Ste Anne
Landmark
Steinbach
Otterburne
Rat River
Grunthal
Sarto
Sandilands
St Labre
Woodridge
Panet
Arnaud
Plum Coulee
Morden
Winkler
Rosenfeld
Altona
Gretna
Emerson
Pembina
Dominion City
Gardenton
Sundown
Tolstoi
Caribou
Noonan
Humboldt
Orleans
Lancaster
Hallock
Lake Bronson
Halma
Kennedy
Donaldson
Karlstad
Strandquist
Strathcona
Middle River
Greenbush
Badger
Haugo
Cavalier
Hamilton
Walhalla
Leroy
Leyden
Backoo
Hill Siding
Mountain
Glasston
Bowesmont
Maffson
Saint Thomas
Gardar
Crystal
Drayton
Auburn
Hoople
Fairdale
Adams
Park River
Nash
Stephen
Florian
Ellerth
Newfolden
Argyle
Holt
Mud L.
Pisek
Lankin
Voss
Minto
Big Woods
Forest River
Ardoch
Alvarado
Warren
Viking
Whitman
Dahlen
Inkster
Fordville
Oriska
Gilby
Manvel
Honeyford
Northland
Tabor
Angus
Sherack
Thief River Falls
St Hilaire
Lakota
Michigan
Mayville
Portland
Hillsboro
Grandin
Buxton
Reynolds
Page
Hatton
Northwood
Larimore
Mekinock
Aneta
Nekoma
Cando
Rolla
Rolette
Dunseith
Bottineau
Westhope
Newburg
Souris
Kenmare
Upham
Granville
Berthold
Carpio
Donnybrook
Bowbells
Lignite
Powers Lake
Tioga
Stanley
Ross
Epping
Alexander
Arnegard
Watford City
Keene
Parshall
New Town
Sanish
Plaza
Mohall
Sherwood
Glenburn
Maxbass
Foxholm
Velva
Karlsruhe
Drake
Anamoose
Harvey
Wilton
Goodrich
Max
Ryder
Makoti
Coleharbor
Underwood
Garrison
Riverdale
Turtle Lake
Washburn
Wilton
Center
Hazen
Beulah
Zap
Hannover
Mandaree
Twin Buttes
Halliday
Dunn Center
Killdeer
Manning
Dickinson
Belfield
Medora
Gladstone
Richardton
Taylor
Hebron
Glen Ullin
New Salem
Almont
Flasher
Carson
Solen
Cannonball
Fort Yates
Selfridge
Kintyre
Shields
Wilton
Hague
Mandan
Bismarck
Lincoln
Menoken
Sterling
Wing
Braddock
Steele
Tappen
Dawson
Streeter
Medina
Pingree
Buchanan
Cleveland
Jamestown
Spiritwood
Kensal
Montpelier
Gackle
Pingree
Buchanan
Cleveland
Sanborn
Courtenay
Enderlin
Sheldon
Fingal
Wimbledon
Dazey
Grace City
Sykeston
Wells
Harvey
Carrington
Bordulac
Sutton
Edmunds
Pettibone
Cathay
Wishek
Ashley
Venturia
Napoleon
Gackle
Streeter
Medina

When the streamflow records of the Red River at Emerson discharge station are compared with the records at Drayton, including all gauged tributaries within the reach, the flows at Emerson are generally lower than at Drayton.

When monthly mean discharge values are compared, those at Emerson are lower than at Drayton, for January to April, July to October, and December. However, the values at Emerson are higher than at Drayton for May, June and November. These observations were based on the period of 1971 to 1980 and are summarized in Table 1. In Table 1, ACC represents the average correction coefficient required to convert Drayton (including tributaries) monthly mean flows to Emerson monthly flows and SD, its standard deviation. For example, based on the monthly flow in January, an average correction coefficient of 0.937 was computed, i.e., the monthly flow summation of Drayton and gauged tributaries is, on average, 6.3% higher than Emerson monthly flow.

Table 1. Average Correction Coefficient for Monthly Flows (1971-80)

Month	ACC	SD
January	0.937	0.073
February	0.927	0.063
March	0.872	0.080
April	0.950	0.120
May	1.144	0.118
June	1.039	0.062
July	0.981	0.053
August	0.992	0.082
September	0.961	0.052
October	0.964	0.059
November	1.001	0.075
December	0.949	0.108

Notes: $ACC = Q_{Emerson} / Q_{Drayton}$
If ACC > 1, then $Q_{Emerson} > Q_{Drayton}$

To illustrate the extent of the problem during the winter ice period, the differences between Drayton (excluding tributaries, because during the winter period, tributary inflow is negligible) and Emerson monthly mean flows for December to February for a longer period (1962 to 1983) were computed (Table 2). December to February represents the winter period with steady flow and solid ice cover where complex flow computation technique is not used. The difference between the two streamflow stations is expressed in the form of an average correction required to convert Drayton to Emerson and is calculated as the ratio of Emerson to Drayton. Also given in Table 2 are the standard deviation, maximum, and minimum value of the average correction coefficient.

Table 2. Average Correction Coefficient for Winter Period (1962-83)

Month	ACC	SD	MAX	MIN
December	0.992	0.113	1.222	0.812
January	0.969	0.067	1.112	0.775
February	0.951	0.064	1.103	0.801

Notes: $ACC = Q_{Emerson} / Q_{Drayton}$
If ACC > 1, then $Q_{Emerson} > Q_{Drayton}$

A graphical representation of these coefficients, through time, is presented in Figure 10.

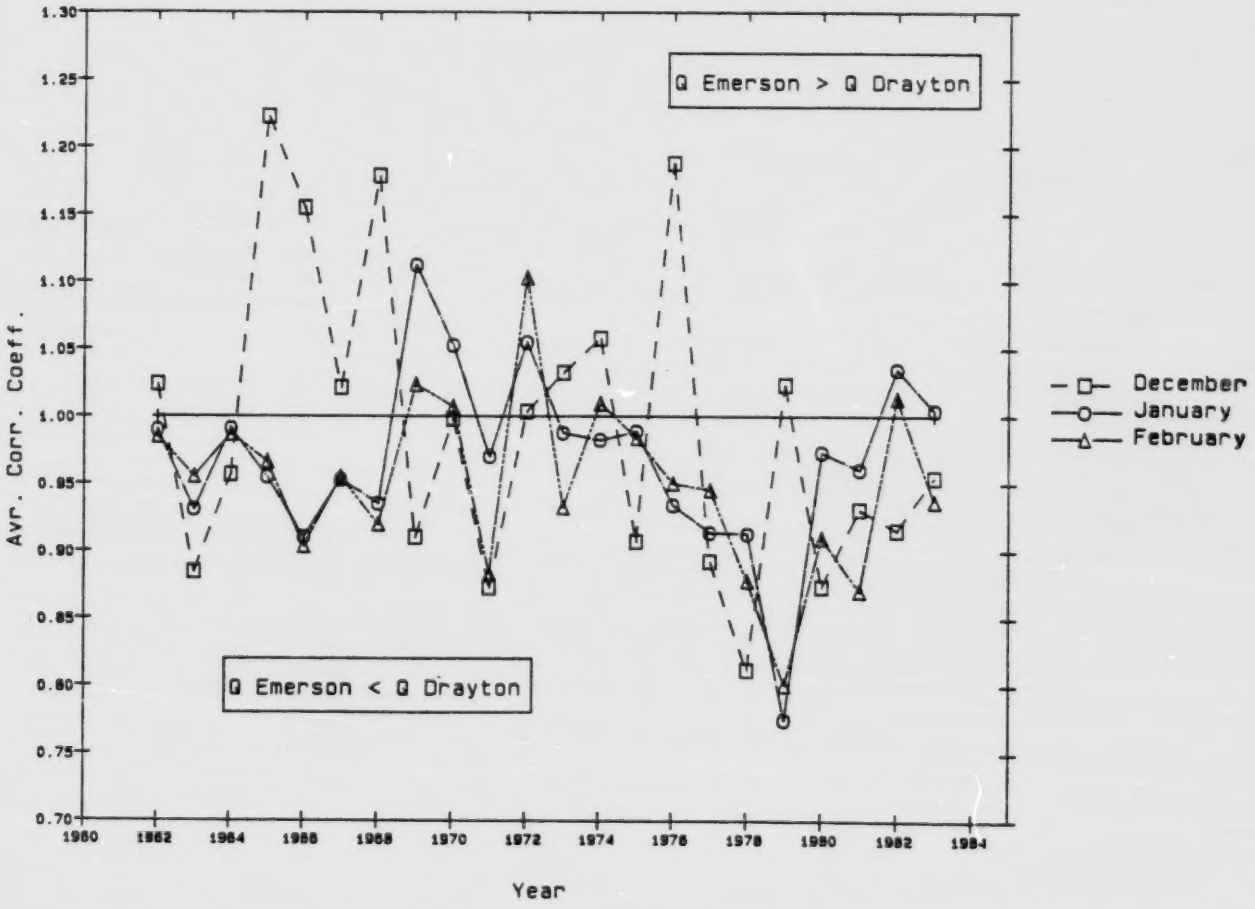


Figure 10. Comparison of monthly mean flow at Emerson and Drayton (1962-83).

Differences in winter streamflow records, between Drayton and Emerson, were noted during the joint review and approval of records by the U.S. Geological Survey and Water Survey of Canada. On the basis of the differences, the initial flow values were usually adjusted prior to publication to provide a compromise.

Over this 22-year period, the published monthly mean flows for Drayton were higher than for Emerson 80% of the time. A review of losses due to ice formation and to supply of an underground aquifer indicated that they could not be responsible for losses of the magnitude observed. It had also been noted that when the U.S. Geological Survey took measurements at Emerson within a short time of those by the Water Survey of Canada, there was usually a significant difference.

In January 1979, a metering program was carried out by Water Survey of Canada and by the U.S. Geological Survey on the Red River at Emerson. Several measurements were taken during a two-day period. Equipment used consisted of WSC winter meters on cable and on rod suspension, and USGS Vane ice meters on rod suspension. The report on this investigation was never completed (Sawatzky, 1979) and was considered to be inconclusive.

The discharge measurements taken on the Red River at Emerson during the winter (period 1963 to 1985) by Water Survey of Canada and by the U.S. Geological Survey were reviewed. The comparison showed that discharge measurements taken by U.S. Geological Survey are generally 10% to 20% higher than those taken by Water Survey of Canada. A comparison of discharge measurements is presented in Table 3.

In summary, it has been demonstrated that the U.S. Geological Survey generally measured higher streamflows, under ice conditions, than the Water Survey of Canada on the Red River at Emerson. It has also been shown that monthly mean flows during the winter period are generally higher at Drayton than at Emerson. Moreover, if the USGS measures higher streamflows, under ice cover, than WSC at Emerson, this might indicate that streamflows measured by the USGS at Drayton are higher than they would have been if they had been measured by WSC, explaining the differences noted between Drayton and Emerson monthly mean flows.

Consequently, the objectives of the study are:

(a) to determine the reason(s) for differences between streamflow measurement obtained under ice conditions by the U.S. Geological Survey and by Water Survey of Canada;

(b) to recommend a plan to reduce and, if possible, eliminate these differences.

Table 3. Field Measurements under Ice Conditions

Date	Crew	Mean Gauge Height (ft)	Measured Discharge (cfs)	Difference USGS/WSC (%)	Equipment (Suspension-Meter)
84-02-07	WSC	750.46	1240	+20.2	Cable - Price
84-02-21	USGS	750.57	1490		Rod - Vane
83-01-05	WSC	750.48	1460	+18.8	Cable - Price
83-01-13	USGS	750.93	1734		Rod - Vane
82-01-05	WSC	749.64	1045	+20.6	Cable - Price
82-01-11	USGS	749.59	1260		Rod - Vane
81-01-13	USGS	746.56	298		Rod - Vane
81-02-03	WSC	746.61	253	+17.8	Rod - Price
80-01-15	WSC	750.19	1350	- 1.5	Cable - Price
80-01-30	USGS	750.13	1330		Rod - Vane
79-01-30	WSC	748.15	527	+22.0, +26.8	Rod - Price
79-01-30	WSC	748.15	551	+16.7, +21.2	Cable - Price
79-01-30	WSC	748.15	487	+32.0, +37.2	Cable - Price
79-01-30	WSC	748.15	561	+14.2, +19.1	Rod - Price
79-01-30	USGS	748.15	643		Rod - Vane
79-01-30	USGS	748.15	668		Rod - Vane
78-01-06	WSC	750.19	1190	+18.5	Cable - Price
78-01-06	USGS	750.19	1410		Rod - Vane
77-01-04	USGS	746.00	170		Rod - Vane
77-01-14	WSC	746.21	187	- 9.1	Rod - Price
76-02-05	WSC	751.10	1530	+12.4	Cable - Price
76-02-09	USGS	751.12	1720		Rod - Vane
75-02-05	WSC	750.06	1350	+ 3.7	Cable - Price
75-02-11	USGS	750.19	1400		Rod - Vane
73-01-11	USGS	749.49	1390		Rod - Vane
73-01-17	WSC	749.52	1090	+27.5	Cable - Price
72-01-11	USGS	751.13	2160		Rod - Vane
72-02-02	WSC	751.15	1650	+30.9	Cable - Price
71-01-07	USGS	749.26	1070		Rod - Vane
71-01-22	WSC	749.32	1000	+ 7.0	Cable - Price

Table 3. Continued

Date	Crew	Mean Gauge Height (ft)	Measured Discharge (cfs)	Difference USGS/WSC (%)	Equipment (Suspension-Meter)
69-01-14	WSC	750.65	1760	- 4.0	Cable - Price
69-01-14	USGS	750.66	1690		Rod - Vane
68-01-03	USGS	747.54	625		Rod - Vane
68-01-10	WSC	747.48	445	+40.4	Cable - Price
67-01-10	WSC	750.91	1730	+ 1.2	Cable - Price
67-01-10	USGS	750.91	1750		Rod - Vane
65-01-06	WSC	748.83	762	+20.2	Cable - Price
65-01-06	USGS	748.83	916		Rod - Vane
63-01-02	USGS	749.88	1380		Rod - Vane
63-01-03	WSC	-	986	+40.0	Cable - Price

2.5 Methodology

In general, discharge measurements taken by the USGS using a Vane ice meter mounted on rods are approximately 10% to 20% higher than those taken by the WSC using a WSC winter meter mounted on rods, winter weight assemblies, or hand lines. The variation in the measurements may be attributed to differences in (a) streamflow measurement procedures; (b) suspension equipment; (c) current meter rating procedure; and (d) current meter design. The hydrometric (metering) standards used by the two agencies did not differ significantly except in this respect.

To explain and resolve these differences, the following methodology was developed, which includes

(1) The International metering program on the Red River at Drayton, North Dakota, and at Emerson, Manitoba;

(2) Calibration of current meters at the calibration service of Water Survey of Canada at Canada Centre for Inland Waters (CCIW), National Water Research Institute;

(3) Calibration of current meters at the calibration section of the U.S. Geological Survey at the Hydrologic Instrumentation Facility (HIF);

(4) Testing of current meters in flowing water under controlled conditions, i.e. 1-m flume at Canada Centre for Inland Waters;

(5) Analysis of the data collected in the field and in the laboratory.

3. FIELD AND LABORATORY EXPERIMENTS

An International Metering Program was conducted in January 1986 on the Red River by Water Survey of Canada and the U.S. Geological Survey. Its results are summarized in Section 3.1. The equipment, i.e. current meters, used in the field was rated on several occasions, in Canada and in the United States. The results of these ratings are presented in Section 3.2. All the field and experimental data were entered into an integrated data analysis system "RS/1" (Bolt Beranek and Newman, 1983) for further analysis. The data are analyzed in Section 4.

3.1 Field Experiments

The field experiments conducted in 1979 by the two agencies provided a good basis for the establishment of the 1986 International Metering Program on the Red River at Drayton, N.D., on January 21, and at Emerson, Man., on January 22 and 23. Two cross sections were selected each day for verification and comparison purposes.

3.1.1 Red River at Drayton

On January 21, 1986, streamflow measurements under ice conditions were obtained by the USGS crew and by the two WSC crews (WSC1 and WSC2) on the Red River at Drayton. Streamflow measurements were performed at two cross sections: cross section 1 located 100 m upstream from the highway bridge, 2.5 km northeast of Drayton, and cross section 2, 50 m upstream from cross section 1. Cross section 1 is the metering section normally used for winter discharge measurement at Drayton.

The characteristics of each cross section at Drayton were as follows:

Cross section	Crew	Width (m)	Area (m^2)	Maximum Depth (m)	Ice Thickness (m)
1	WSC1, USGS	89	207	3.5	0.3-0.4
2	WSC2	89	202	3.5	0.3-0.4

The following equipment was used by each crew:

WSC1: WSC winter meter 6-356 on winter rods
WSC2: WSC winter meter 6-288 on winter rods
USGS: Vane ice meter I-39 on ice rods

The WSC1 and USGS crews each performed two simultaneous streamflow measurements at cross section 1. Verticals and water edges were the same for both. The same standard soundings (i.e. predetermined depth in vertical) were used for the second measurement.

WSC2 performed three streamflow measurements at cross section 2, 50 m upstream from cross section 1.

The field measurements are summarized in Table 4. Three vertical velocity profiles were also obtained by the Canadian (WSC1) and American (USGS) crews at cross section 1 (Table 5). The original field data were processed using RS/1, a data analysis program (Bolt, Beranek and Newman, 1983) and are presented in Appendix B.

Table 4. Field Measurements, Red River at Drayton, January 21, 1986

Crew	Suspension	Meter	Number of Verticals	Width (m)	Area (m^2)	Mean Velocity* (m/s)	Discharge (m^3/s)
Measurement No. 1							
WSC1	Rod	6-356	26	89+	205.7	0.272	55.9
WSC2	Rod	6-288	22	89	201.9	0.266	53.7
USGS	Rod	I-39	26	89+	208.5	0.274	57.1
Measurement No. 2							
WSC1	Rod	6-356	26	89+	207.4+	0.268	55.5
WSC2	Rod	6-288	24	89	201.9	0.270	54.5
USGS	Rod	I-39	26	89+	207.3+	0.274	56.7
Measurement No. 3							
WSC2	Rod	6-288	24	89	202.5	0.265	53.7

* Mean velocities computed with original current meter rating equation.
+ Predetermined to be the same.

Table 5. Vertical Velocity Profiles, Red River at Drayton, January 21, 1986

Point Velocity* (m/s) in Vertical 30 ft

Crew \ d	0.1 D	0.2 D	0.3 D	0.4 D	0.5 D	0.6 D	0.7 D	0.8 D	0.9 D
WSC1	0.261	0.308	0.315	0.308	0.291	0.299	0.264	0.296	0.246
USGS	0.291	0.309	0.323	0.323	0.316	0.285	0.285	0.274	0.233

Point Velocity* (m/s) in Vertical 49 ft

Crew \ d	0.1 D	0.2 D	0.3 D	0.4 D	0.5 D	0.6 D	0.7 D	0.8 D	0.9 D
WSC1	0.302	0.333	0.331	0.373	0.353	0.331	0.310	0.279	0.244
USGS	0.297	0.323	0.347	0.347	0.339	0.331	0.316	0.267	0.255

Point Velocity* (m/s) in Vertical 67 ft

	0.1 D	0.2 D	0.3 D	0.4 D	0.5 D	0.6 D	0.7 D	0.8 D	0.9 D
WSC1	0.272	0.299	0.307	0.311	0.297	0.286	0.276	0.266	0.226
USGS	0.279	0.285	0.303	0.309	0.316	0.297	0.285	0.238	0.206

	Mean velocity* (m/s) in Verticals		
	30ft	49ft	67ft
WSC1	0.288	0.317	0.282
USGS	0.293	0.314	0.280

* Velocities computed with original current meter rating equation.

3.1.2 Red River at Emerson

On January 22 and 23, 1986, streamflow measurements under ice conditions were obtained by the USGS crew, and by the two WSC crews on the Red River at Emerson. On January 22, streamflow measurements were performed at two cross sections: cross section 1 located at the gauge, i.e., 500 m downstream from the CNR bridge and 1.2 km downstream from the International Boundary, and cross section 2, 50 m upstream from cross section 1. Cross section 1 is the metering section normally used for winter discharge measurement at Emerson.

The characteristics of each cross section at Emerson were as follows:

Cross section	Crew	Width (m)	Area (m^2)	Maximum Depth (m)	Ice Thickness (m)
1	WSC1, USGS	70	172	3.8	0.3-0.45
2	WSC2	71	180	4.4	0.3-0.45

The series of two measurements obtained by each crew on January 22 are presented in Table 6. Vertical velocity profiles were obtained at three verticals on cross section 1 by WSC1 and USGS, and the results are summarized in Table 7.

Table 6. Field Measurements, Red River at Emerson, January 22, 1986

Crew	Suspension	Meter	Number of Verticals	Width (m)	Area (m^2)	Mean Velocity* (m/s)	Discharge (m^3/s)
Measurement No. 1							
WSC1	Rod	6-356	23	70	170.9	0.328	56.1
WSC2	Rod	6-288	23	71	179.5	0.306	55.0
USGS	Rod	I-39	23	70	173.2	0.332	57.5
Measurement No. 2							
WSC1	Rod	6-356	23	70	170.4	0.325	55.4
WSC2	Rod	6-288	23	71	180.3	0.309	55.7
USGS	Rod	I-39	23	70	172.5	0.338	58.3

* Mean velocities computed with original current meter rating equation.

Table 7. Vertical Velocity Profiles, Red River at Emerson, January 22, 1986

Point Velocity* (m/s) in Vertical 6 m

Crew \ d	0.1 D	0.2 D	0.3 D	0.4 D	0.5 D	0.6 D	0.7 D	0.8 D	0.9 D
WSC1	0.212	0.232	0.243	0.234	0.234	0.249	0.238	0.257	0.210
USGS	0.158	0.192	0.198	0.210	0.213	0.213	0.213	0.213	0.192

Point Velocity* (m/s) in Vertical 9 m

Crew \ d	0.1 D	0.2 D	0.3 D	0.4 D	0.5 D	0.6 D	0.7 D	0.8 D	0.9 D
WSC1	0.253	0.268	0.279	0.279	0.274	0.279	0.239	0.234	0.177
USGS	0.250	0.262	0.274	0.287	0.280	0.280	0.250	0.229	0.180

Point Velocity* (m/s) in Vertical 12 m

	0.1 D	0.2 D	0.3 D	0.4 D	0.5 D	0.6 D	0.7 D	0.8 D	0.9 D
WSC1	0.274	0.329	0.278	0.297	0.275	0.262	0.261	0.243	0.208
USGS	0.262	0.256	0.287	0.290	0.287	0.268	0.262	0.223	0.186

Mean velocity* (m/s) in Verticals

	6 m	9 m	12 m
WSC1	0.234	0.254	0.270
USGS	0.200	0.255	0.258

* Velocities computed with original current meter rating equation.

On January 23, all the streamflow measurements were performed at the same cross section, i.e. cross section 1 used the previous day by WSC1 and USGS.

The equipment used by WSC1 and the USGS was not changed. A modification, however, was made to the WSC2 equipment, i.e., the same meter was used but with a different type of suspension: WSC winter meter 6-288 on cable suspension with a Winnipeg winter weight assembly, as commonly used in deeper waters and often at Emerson by WSC. The instruments are shown in Figure 11.

The series of two streamflow measurements taken on the Red River at Emerson, on January 23, 1986, are presented in Table 8.

Velocity observations were also taken in three verticals during a 10-min period, using the 0.2 and 0.8 depth method. The observations were taken because a significant pulsation effect was observed by field crews. These observations are summarized in Tables 9 to 11. The velocities were computed using the original current meter rating equations as well as the composite rating equations developed at CCIW in February 1986.

The original field data, for January 22 and 23, are presented in Appendix B.

Differences between USGS and WSC streamflow measurements were observed during the field investigation. In particular, it was noted that the velocities, as measured by the USGS, were generally higher than those of the WSC. Also, discharge measurements performed with the WSC winter meter on cable suspension seemed to be significantly lower than measurements performed with the WSC meter on rod suspension, or with the Vane meter on rod suspension. The field data collected during the period January 21-23 will be fully analyzed and discussed in Section 4.

Figure 11. Equipment used by USGS and WSC personnel.

Table 8. Field Measurements, Red River at Emerson, January 23, 1986

Crew	Suspension	Meter	Number of Verticals	Width (m)	Area (m^2)	Mean Velocity* (m/s)	Discharge (m^3/s)
Measurement No. 1							
WSC1	Rod	6-356	23	70	170.8	0.331	56.5
WSC2	Cable	6-288	23	70	169.8	0.305	51.8
USGS	Rod	I-39	23	70	172.5	0.347	59.8
Measurement No. 2							
WSC1	Rod	6-356	23	70	170.1	0.336	57.2
WSC2	Cable	6-288	23	70	170.6	0.298	50.8
USGS	Rod	I-39	23	70	172.8	0.344	59.4

* Mean velocities computed with original current meter rating equation.

Table 9. Velocity Pulsations (WSC1), Red River at Emerson, January 23, 1986

Crew	Suspension	Meter	Obs. at Min.+	Mean Velocity in Vertical (m/s) 6 m 0.2d	6 m 0.8d	9 m 0.2d	9 m 0.8d	12 m 0.2d	12 m 0.8d
WS1	Rod	6-356	1	0.225	0.216	0.274	0.203	0.281	0.209
			2	0.224	0.220	0.264	0.228	0.283	0.205
			3	0.231	0.228	0.269	0.226	0.289	0.240
			4	0.227	0.229	0.270	0.224	0.284	0.249
			5	0.228	0.244	0.277	0.207	0.292	0.230
			6	0.230	0.239	0.270	0.230	0.288	0.212
			7	0.225	0.232	0.261	0.233	0.287	0.209
			8	0.239	0.240	0.277	0.223	0.278	0.221
			9	0.235	0.231	0.274	0.236	0.287	0.242
			10	0.236	0.249	0.269	0.213	0.290	0.220
Mean				0.230	0.233	0.271	0.222	0.286	0.224
Standard Deviation				0.005	0.010	0.005	0.011	0.004	0.016
Percentage Standard Deviation (95% level)				4.35	8.58	3.69	9.91	2.80	14.3
Original Mean*				0.229	0.232	0.268	0.222	0.283	0.223

Note: Composite rating equation developed in February 1986 was used.
$V = 0.6916\ N + 0.0043$ for $N < 0.564$ rev/s
$V = 0.6712\ N + 0.0158$ for $N \geq 0.564$ rev/s

+ Velocity observations taken in three verticals during a 10-min period, using the 0.2 and 0.8 depth method.

* Mean velocities computed with original current meter rating equation.

Table 10. Velocity Pulsations (WSC2), Red River at Emerson, January 23, 1986

Crew	Suspension	Meter	Obs. at Min.+	Mean Velocity in Vertical (m/s) 6 m 0.2d	6 m 0.8d	9 m 0.2d	9 m 0.8d	12 m 0.2d	12 m 0.8d
WS2	Cable	6-288	1	0.249	0.228	0.282	0.242	0.290	0.227
			2	0.251	0.229	0.288	0.237	0.283	0.241
			3	0.249	0.216	0.281	0.244	0.286	0.231
			4	0.243	0.227	0.283	0.215	0.274	0.228
			5	0.255	0.229	0.272	0.208	0.286	0.242
			6	0.251	0.236	0.286	0.234	0.281	0.234
			7	0.249	0.229	0.291	0.212	0.290	0.234
			8	0.249	0.234	0.288	0.233	0.283	0.241
			9	0.241	0.230	0.286	0.209	0.272	0.233
			10	0.254	0.227	0.292	0.210	0.291	0.219
Mean				0.249	0.229	0.285	0.224	0.284	0.233
Standard Deviation				0.004	0.005	0.006	0.015	0.007	0.007
Percentage Standard Deviation (95% level)				3.21	4.37	4.21	13.4	4.93	6.01
Original Mean*				0.224	0.204	0.260	0.199	0.258	0.208

Note: Composite rating equation developed in February 1986 was used.
$V = 0.7926\ N + 0.0076$ for $N < 0.156$ rev/s
$V = 0.6878\ N + 0.0239$ for $0.156 \leq N \leq 2.683$ rev/s
$V = 0.7855\ N - 0.2382$ for $N > 2.683$ rev/s

+ Velocity observations taken in three verticals during a 10-min period, using the 0.2 and 0.8 depth method.

* Mean velocities computed with original current meter rating equation.

Table 11. Velocity Pulsations (USGS), Red River at Emerson, January 23, 1986

Crew	Suspension	Meter	Obs. at Min.+	Mean Velocity in Vertical (m/s) 6 m 0.2d	6 m 0.8d	9 m 0.2d	9 m 0.8d	12 m 0.2d	12 m 0.8d
USGS	Rod	I-39	1	0.240	0.245	0.262	0.251	0.288	0.269
			2	0.230	0.245	0.269	0.245	0.288	0.235
			3	0.235	0.245	0.275	0.235	0.293	0.275
			4	0.240	0.240	0.275	0.230	0.288	0.262
			5	0.240	0.240	0.269	0.262	0.293	0.251
			6	0.240	0.245	0.275	0.245	0.306	0.256
			7	0.235	0.262	0.275	0.240	0.293	0.262
			8	0.245	0.245	0.269	0.230	0.288	0.230
			9	0.235	0.230	0.282	0.221	0.299	0.269
			10	0.240	0.251	0.282	0.235	0.306	0.245
Mean				0.238	0.245	0.273	0.239	0.294	0.255
Standard Deviation				0.004	0.008	0.006	0.012	0.007	0.015
Percentage Standard Deviation (95% level)				3.36	6.53	4.40	10.0	4.76	11.8
Original mean*				0.230	0.237	0.266	0.232	0.286	0.249

Note: Composite rating equation developed in February 1986 was used.
$V = 0.7263\ N + 0.0029$ for $N < 0.857$ rev/s
$V = 0.6878\ N + 0.0359$ for $N \geq 0.857$ rev/s

+ Velocity observations taken in three verticals during a 10-min period, using the 0.2 and 0.8 depth method.

* Mean velocities computed with original current meter rating equation.

3.2 Laboratory Experiments

3.2.1 Rating of Current Meters

A current meter rating is obtained by towing the meter through still water at various velocities and recording the number of revolutions of the rotor in a measured interval of time for each pre-selected velocity.

The present practice in Canada and the United States to obtain current meter rating equations is to perform linear regressions on the calibration data. The general form of the calibration equation is

$$V = a + bN$$

where V is the speed of the meter rotor towed through still water, N is the revolution rate of the meter rotor, a is an intercept, and b is the slope of the equation.

In Canada, all WSC winter current meters receive individual calibrations by the National Calibration Service at Canada Centre for Inland Waters and, as a rule, are rated every three years, or after being damaged in service. The WSC winter meter is calibrated on rigid rod suspension only. A single rating is provided along with the meter.

In the United States, the Vane ice meter is individually calibrated, and a composite rating is supplied with the meter. However, the meter is not rated again after a certain period in service. Instead, the pivot is replaced by the field staff if the meter does not satisfy the pre-measurement test ("spin" test). If the meter is damaged, it is sent to be repaired and then rated.

It is interesting to note that each Price current meter, in Canada, is individually rated, and a single rating (one linear equation) is provided with the meter. In contrast, since 1968 in the United States (Smoot and Carter, 1968), the Price meters are group-rated and a composite rating (two or more linear equations) provided for all meters in the group.

All of the meters used in the field investigation were calibrated ("as received" condition) simultaneously in a large towing tank (Fig. 12), 122 m (400 ft) long, 5 m (16 ft) wide, and 3 m (10 ft) deep at the National Calibration Service of Environment Canada in February and September of 1986. The meters were re-calibrated to determine whether changes had occurred since previously calibrated.

The towing carriage is capable of providing speeds from 0.5 cm/s to 600 cm/s (0.02 ft/s to 19.7 ft/s) with better than $\pm$1% accuracy at any speed (Engel, 1976).

The Canadian calibration tests included the development of the following ratings:

(i) standard ratings (20 runs, i.e. at 20 different velocities) with velocities ranging from 10 to 250 cm/s (0.3 to 8.2 ft/s);

(ii) special ratings (31 runs) with velocities ranging from 2 to 250 cm/s (0.07 to 8.2 ft/s);

(iii) low speed ratings (30 runs) with velocities ranging from 3 to 60 cm/s (0.1 to 1.97 ft/s).

Single (one linear equation) and composite (two or more linear equations) ratings were developed in most cases. Rod and cable suspension was used in the calibration of meter WSC 6-288, and rod only for meters WSC 6-356 and I-39.

The current meters were also calibrated ("as received" condition) in the United States by the National Calibration Service of the U.S. Geological Survey in March 1986. The calibration tests included development of standard ratings (20 runs, i.e., ten different velocities but in both directions) with velocities ranging from 0.1 to 8 ft/s (3 to 244 cm/s).

Single and composite equations were developed. Rod and cable suspension was used in the calibration of WSC meter 6-288, and rod only in the calibration of meters WSC 6-356 and I-39.

A summary of the calibration tests for each meter is presented in Tables 12 to 14 for the WSC winter meter 6-356, WSC winter meter 6-288, and Vane ice meter I-39, respectively, along with their original ratings used during the field work. The complete calibration data are presented in Appendix C.

There was no adjustment or use of any of the meters between the field experiments and the calibration runs in both countries, but from the various ratings and suspensions, differences can be seen in the second and even in the first significant digit in the current meter rating equations.

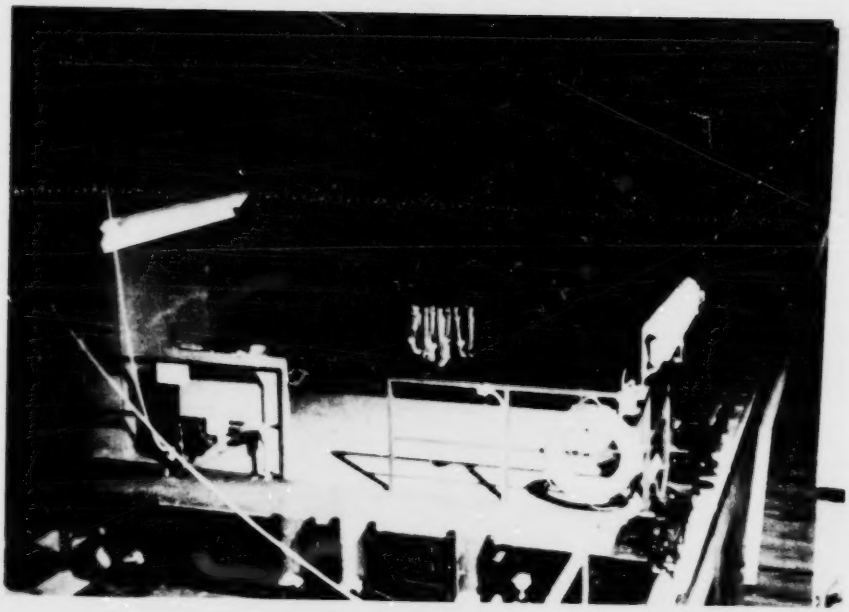


Figure 12. Towing tank at CCIW.

Table 12. Calibration Data for WSC Winter Meter 6-356

Date of Calibration	Equations* (m/s)	Range (rev/s)	Standard Error (m/s)	Suspension	Rating Tank Runs	Velocity Range (cm/s)	Site	Remarks
84-10-01	0.6679 N + 0.0114			Rod			CCIW	Initial Rating
86-02-05	0.6736 N + 0.0101		0.005	Rod	31	2-250	CCIW	Single Rating
86-02-05	0.6916 N + 0.0043 0.6712 N + 0.0158	N < 0.564 N ≥ 0.564	0.002 0.004	Rod	31	2-250	CCIW	Composite Rating
86-02-05	0.5520 N + 0.0467		0.014	Rod	8	18-36	CCIW	Fluctuating Vel. Single Rating
86-03-18	0.6846 N + 0.0049		0.003	Rod	20	3-244	HIF	Single Rating
86-03-18	0.6800 N + 0.0070 0.6913 N - 0.0140	N < 1.833 N ≥ 1.833	0.002	Rod	20	3-244	HIF	Composite Rating
86-09-18	0.6708 N + 0.0044		0.003	Rod	20	10-250	CCIW	Single Rating
86-09-18	0.6690 N + 0.0078		0.004	Rod	30	3-60	CCIW	Low Speed Single Rating
86-09-18	0.6014 N + 0.0176 0.6794 N + 0.0012	N < 0.210 N ≥ 0.210	0.002 0.002	Rod	30	3-60	CCIW	Low Speed Composite Rating

* V (m/s) = b N + a where N is in rev/s.

Table 13. Calibration Data for WSC Winter Meter 6-288

Date of Calibration	Equations* (m/s)	Range (rev/s)	Standard Error (m/s)	Suspension	Rating Tank Runs	Velocity Range (cm/s)	Site	Remarks
84-08-23	0.6840 N + 0.0000			Rod				
86-02-05	0.6775 N + 0.0082		0.0030	Rod	31	2-250	CCIW	Initial Rating
86-02-05	0.6840 N + 0.0054	N < 0.965	0.0030	Rod	31	2-250	CCIW	Single Rating
	0.6752 N + 0.0139	N ≥ 0.965	0.0030					Composite Rating
86-02-05	0.7001 N + 0.0145		0.0140	Cable	30	3-250	CCIW	Single Rating
86-02-05	0.7926 N + 0.0076	N1 < 0.156	0.0030	Cable	30	3-244	CCIW	Composite Rating
	0.6878 N + 0.0239	N1 ≤ N ≤ N2	0.0040					
	0.7855 N - 0.2382	N2 > 2.683	0.0030					
86-02-05	0.6441 N + 0.0357		0.0050	Cable	10	18-36	CCIW	Fluctuating Vel. Single Rating
86-03-18	0.6898 N + 0.0052		0.0057	Rod	20	3-244	HIF	Single Rating
86-03-18	0.6834 N + 0.0082	N < 2.150	0.0027	Rod	20	3-244	HIF	Composite Rating
	0.7047 N - 0.0375	N ≥ 2.150						
86-03-20	0.7178 N - 0.0012		0.0177	Cable	20	3-244	HIF	Single Rating
86-03-20	0.6934 N + 0.0098	N < 2.056	0.0033	Cable	20	3-244	HIF	Composite Rating
	0.7727 N - 0.1530	N ≥ 2.056						
86-09-18	0.6882 N + 0.0060		0.0030	Rod	20	10-250	CCIW	Single Rating
86-09-18	0.6793 N + 0.0109	N < 0.810	0.0027	Rod	20	10-250	CCIW	Composite Rating
	0.6898 N + 0.0024	N ≥ 0.810	0.0023					
86-09-18	0.6824 N + 0.0094		0.0033	Rod	30	3-60	CCIW	Low Speed Single Rating
86-09-18	0.6536 N + 0.0148	N < 0.328	0.0033	Rod	30	3-60	CCIW	Low Speed Composite Rating
	0.6957 N + 0.0010	N ≥ 0.328	0.0016					
86-09-23	0.7090 N + 0.0160		0.0113	Cable	17	20-250	CCIW	Single Rating
86-09-23	0.6648 N + 0.0125	N1 < 0.739	0.0027	Cable	20	20-250	CCIW	Composite Rating
	0.7028 N - 0.0156	N1 ≤ N ≤ N2	0.0024					
	0.7479 N - 0.1276	N2 > 2.483	0.0010					

* V (m/s) = b N + a where N is in rev/s.

Table 13. Continued

Date of Calibration	Equations* (m/s)	Range (rev/s)	Standard Error (m/s)	Suspension	Rating Tank Runs	Velocity Range (cm/s)	Site	Remarks
86-09-23	0.6776 N + 0.0119		0.0033	Cable	30	3-60	CCIW	Low Speed Single Rating
86-09-23	0.6926 N + 0.0084 0.6567 N + 0.0262	N < 0.496 N ≥ 0.496	0.0022 0.0027	Cable	30	3-60	CCIW	Low Speed Composite Rating

Table 14. Calibration Data for USGS Vane Meter I-39

Date of Calibration	Equations* (m/s)	Range (rev/s)	Standard Error (m/s)	Suspension	Rating Tank Runs	Velocity Range (cm/s)	Site	Remarks
76-09-21	0.7041 N + 0.0034 0.6773 N + 0.0134	N < 0.426 N > 0.426		Rod			HIF	Initial Rating 0.03-0.30 m/s 1981 0.30-1.52 m/s 1976
86-02-05	0.6968 N + 0.0144		0.008	Rod	31	2-250	CCIW	Single Rating
86-02-05	0.7263 N + 0.0029 0.6878 N + 0.0359	N < 0.857 N ≥ 0.857	0.003 0.002	Rod	31	2-250	CCIW	Composite Rating
86-02-05	0.6886 N + 0.0097		0.005	Rod	10	18-36	CCIW	Fluctuating Vel. Single Rating
86-03-20	0.6754 N + 0.0180		0.0137	Rod	20	3-244	HIF	Single Rating
86-03-20	0.7105 N + 0.0049 0.6578 N + 0.0646	N < 1.128 N ≥ 1.128	0.0029	Rod	20	3-244	HIF	Composite Rating
86-09-18	0.6863 N + 0.0223		0.0127	Rod	20	10-250	CCIW	Single Rating
86-09-18	0.7210 N + 0.0022		0.0035	Rod	30	2-60	CCIW	Low Speed Single Rating
86-09-18	0.6884 N + 0.0081 0.7366 N - 0.0074	N < 0.322 N ≥ 0.322	0.0032 0.0017	Rod	30	2-60	CCIW	Low Speed Composite Rating

* V (m/s) = b N + a where N is in rev/s.

3.2.2 Flume Experiments

Flume experiments were conducted to determine whether the WSC winter meter or the Vane ice meter measures flow more precisely under controlled conditions.

The 1-m flume at the Hydraulics Laboratory of the National Water Research Institute at CCIW was used to test the meters in flowing water. The flume is made of steel and aluminum with glass walls (Fig. 13). The interior width, overall length, and height of the walls are, respectively, 1.0, 25.9 and 0.75 m. A slope ranging from 0 to 5% may be obtained. Flow is supplied from a large constant head tank.

Flow can be measured by using the annubar and elbow meters equipped with differential pressure transducers in the delivery line; the tail box, which can be fitted with a variety of different sized weirs; or the volumetric tank, which measures the overflow from the constant head tank. The volumetric method was used and the discharge through the flume determined by $Q_f = Q_p - Q_o$ where Q_f is the discharge in the flume, Q_p is the flow rate pumped into the constant head tank, and Q_o is the overflow in the volumetric tank.

A small carriage (Fig. 14) is mounted on rails on the top of the flume and traverses the length of the flume. The metering equipment was affixed to this carriage.

The following experiments were conducted, respectively, on September 10 and October 3, 1986, in the 1-m flume:

(i) Velocity observations for six different depths using the meter and suspension equipment from the field investigation. The results of these tests are presented in Table 15. The purpose of this test was to identify differences in measured velocities between current meters, and therefore the actual discharge was not precisely determined.

(ii) Streamflow measurements for two cross-sectional areas using meter and rod only. Five verticals across the flume were used to perform the "streamflow" measurements. The volumetric method was used to measure the "true" discharge in the flume. The flow was diverted into the 33 m^3 tank and its filling time determined manually with a stopwatch.

The results of these two tests are summarized in Table 16.

Another test was conducted on September 10 to determine whether the meters were affected by pulsation or by turbulence. The meters were positioned at midwidth and middepth for 400 consecutive rotor revolutions (approximately 14 min); a reading was taken every ten revolutions. For the three meters tested, the velocity was found to be constant after 30 revolutions. Because no variations were observed in the velocity after approximately 1 min, the data are not presented. The mean velocity given by each meter was very close ($\pm$1%). More flow turbulence could have been introduced to represent actual field conditions by placing obstructions on the stream bed, modifying the composition of the stream bed.

Figure 13. One-metre flume at CCIW.

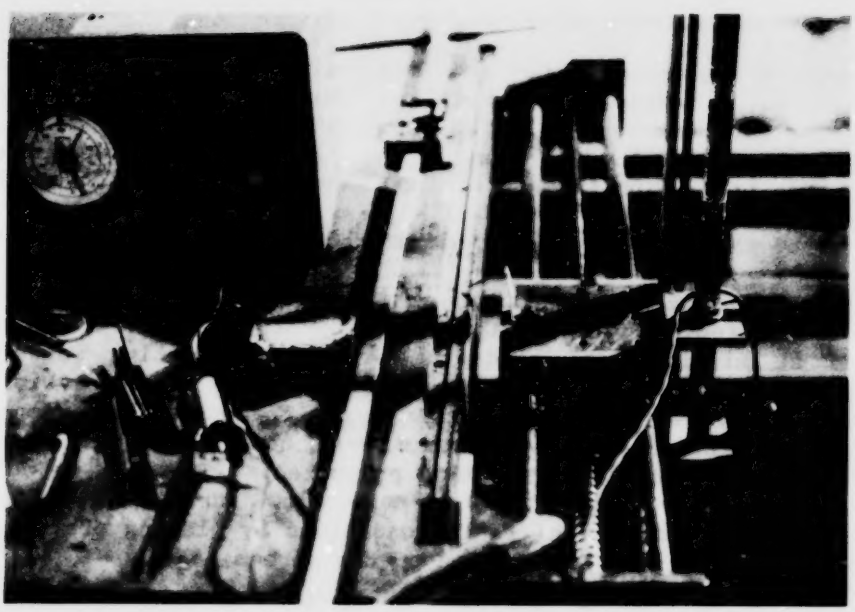


Figure 14. Carriage on 1-m flume.

Table 15. Tests in Flowing Water Performed at CCIW, September 10, 1986

Meter	Suspension	Mean Velocity * (m/s) Run No.+ 1	2	3	4	5	6
6-356	Rod	0.379	0.523	0.602	0.285	0.056	0.174
6-288	Rod	0.401	0.536	0.593	0.294	0.056	0.174
I-39	Rod	0.420	0.545	0.671	0.289	0.060	0.178
6-288	Cable	0.408	0.562	0.615	0.314	0.063	0.192

* Mean velocity was computed using the composite current meter equations (for rod and cable suspensions) developed at CCIW in February 1986. Three velocity observations were used to compute the mean velocity for each run.

+ Total depth and meter depth below surface were different for each run, as follows:

Run No.	Total Depth (cm)	Meter Depth below Surface (cm)
1	41.0	7.5
2	47.5	14.0
3	40.0	6.5
4	44.0	10.5
5	44.7	11.2
6	52.3	18.8

Meter was positioned at midwidth, 0.5 m.

Table 16. Flume Measurements at CCIW

Meter	Suspension	Mean Velocity in Vertical as Positioned from Right to Left Edge (m/s) 0.1 m	0.3 m	0.5 m	0.7 m	0.9 m	Computed Discharge (m^3/s)
Measurement No. 1							
Discharge* = 0.128 m^3/s Depth = 0.446 m Width = 1.000 m							
6-356	Rod	0.291	0.337	0.337	0.333	0.312	0.130
6-288	Rod	0.297	0.334	0.330	0.329	0.303	0.129
I-39	Rod	0.338	0.339	0.333	0.342	0.304	0.133
Measurement No.2							
Discharge* = 0.128 m^3/s Depth = 0.498 m Width = 1.000 m							
6-356	Rod	0.266	0.299	0.299	0.300	0.293	0.131
6-288	Rod	0.267	0.297	0.296	0.297	0.290	0.130
I-39	Rod	0.295	0.301	0.295	0.305	0.281	0.133

*Discharge in flume, for measurements 1 and 2, measured by the volumetric method.

Note: Mean velocities computed using equations developed in February 1986.

4. DATA ANALYSIS

In Section 3, the field and laboratory results were presented and summarized. Here the collected data will be analyzed and discussed.

The differences between USGS and WSC streamflow measurement parameters on the Red River are summarized in Table 17. They are presented in the form of a parameter ratio, e.g., the difference in area (depth) measurement is computed as the ratio of USGS measured area divided by WSC1 measured area.

USGS area measurements are 1% to 1.5% higher than WSC measurements. Mean velocities, as observed by the USGS, are higher than those of WSC by 1% to 15%. These differences result in flow differences in the order of 2% to 17%, the range of magnitude identified in Section 2. In this section, the causes of these differences will be explored and discussed, including the effects of depth soundings, suspension, current meter rating procedures, current meter design, limited number of observations in the vertical, and limited time of exposure.

Table 17. Differences between USGS and WSC Streamflow Measurement Parameters

Date of Measurement	Measurement Number	WSC Crew	Area Ratios	Mean Velocity Ratios	Discharge Ratios
86-01-21	1	WSC1	1.014	1.007	1.021
86-01-21	2	WSC1	1.000	1.022	1.022
86-01-21	1	WSC2	-	-	1.063
86-01-21	2	WSC2	-	-	1.040
86-01-22	1	WSC1	1.013	1.012	1.025
86-01-22	2	WSC1	1.012	1.040	1.052
86-01-22	1	WSC2	-	-	1.045
86-01-22	2	WSC2	-	-	1.047
86-01-23	1	WSC1	1.010	1.048	1.058
86-01-23	2	WSC1	1.016	1.024	1.038
86-01-23	1	WSC2	1.016	1.138	1.154
86-01-23	2	WSC2	1.013	1.154	1.169

Note: $\text{Ratio} = \frac{P_{USGS}}{P_{WSC}}$

where P is the parameter measured by the USGS and WSC, i.e. area, mean velocity, and discharge. If ratio >1, then streamflow parameter measured by USGS was higher than WSC measurement.

4.1 Effect of Depth Soundings (cross-sectional data)

Differences between USGS and WSC depth measurements were computed and are summarized in Table 18. The width was determined by both agencies at Drayton and Emerson before the first measurement and was found to be very close. In fact, the random uncertainty in measuring width is usually considered very small, i.e., less than $\pm$0.5% (ISO, 1979). Uncertainties in width measurements are generally caused by human error in judging water edges. This uncertainty in width might be high for large streams or for streams under ice cover, however, the effect on the discharge is usually negligible. Therefore throughout the field measurement, the same width value was used by the USGS and WSC1, and differences in cross-sectional area are due to depth differences.

The mean difference in measured depth between the USGS and WSC ranged from 0.024 to 0.040 m, over a depth of up to 3.5 m, with standard deviation ranging from 0.025 to 0.035 m. However, this difference in depth or area (using the same width) is considered relatively small when expressed as a percentage, i.e., 1% to 2%. A cross section at Emerson, which shows the differences between American and Canadian depths on January 23 (first measurement), is presented in Figure 15.

The comparison and analysis of depth measurements obtained by the USGS and WSC showed that USGS measurements are generally higher by approximately 0.03 m. This difference is not constant, however, as indicated by the standard deviation (Table 18).

The reason(s) for this variable "systematic" difference is unknown. However, sounding equipment may in part be responsible. Each crew used different equipment:

(i) WSC1 measured the total depth of water with aluminum rods, with graduation every 0.02 m. The ice thickness, i.e. water surface to bottom to ice, was measured with a combined slush remover and ice stick, also graduated every 0.02 m.

(ii) WSC2 measured the total depth with a cable and weight assembly mounted on a tripod with a standard "A" reel. The graduation of the "A" reel is 0.01 m. As for WSC1, the combined slush remover and ice stick was used to measure the ice thickness. This equipment (cable and weight) was used on January 23 at Emerson. On January 21 and 22, however, winter rods had been used, but at different cross sections. No comparisons were possible between WSC2 depth measurements and other crews' results for January 21 and 22.

(iii) USGS used steel rods, graduated every 1/10 ft (0.03 m), to measure the total water depth. To measure the ice thickness, a steel rod ("[" shape) with the same graduation was used.

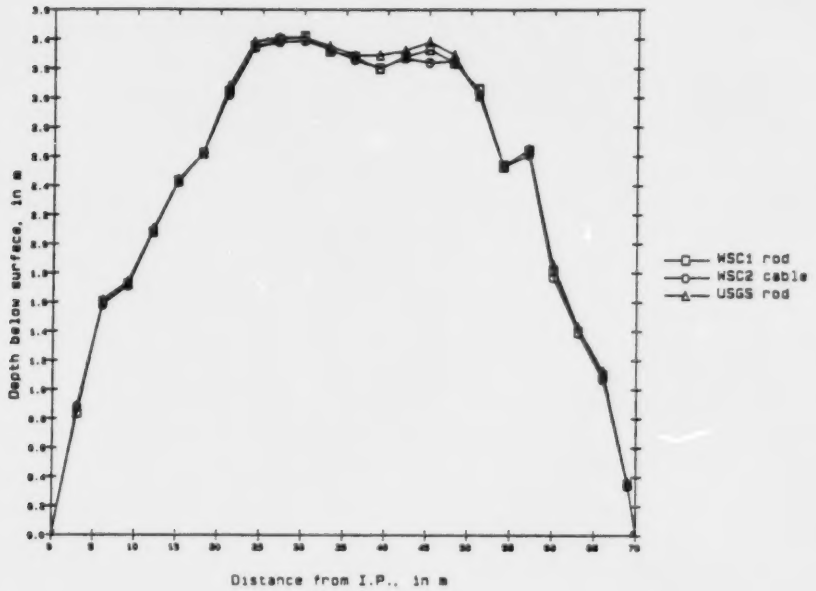


Figure 15a. Differences in depth measured by the USGS and WSC, full cross section, January 23 (1st measurement).

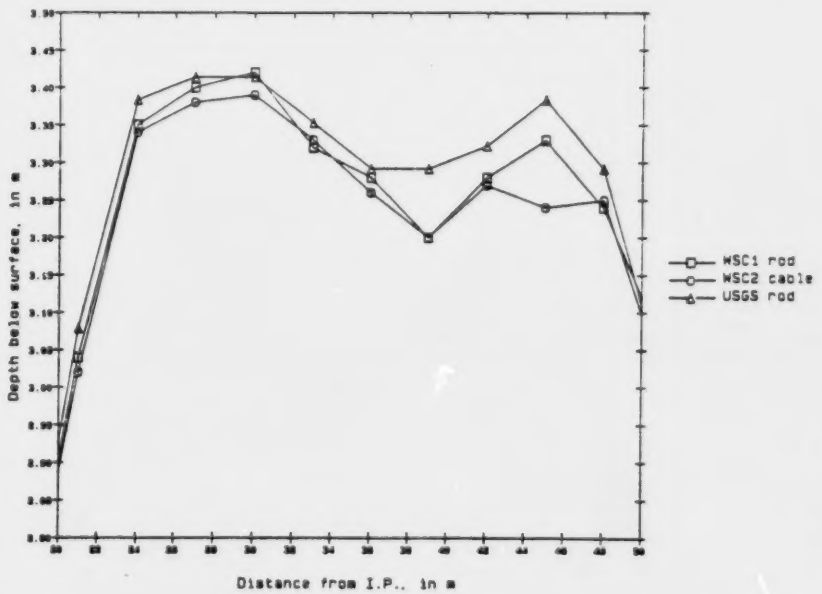


Figure 15b. Differences in depth measured by the USGS and WSC, partial cross section, January 23 (1st measurement).

The material used by the USGS for depth measurements is heavier (steel) than the WSC equipment (aluminum), making the soundings more difficult; the heaviest rods, however, offer more stability during velocity observations. Also, the graduation of the USGS rod is "coarser" when compared with the WSC rod, i.e. 0.030 m (1/10 ft) (USGS) versus 0.02 m (WSC).

Another factor contributing to these observed differences is that soundings with the winter rod set are read from calibrations marked on the body of the rod (Fig. 16).

The circular base of the USGS steel winter rod is 0.15 ft (0.046 m) lower than the 0.0 mark, and this amount (0.15 ft or 0.046 m) must be added to the depth indicated by the calibration marks at every sounding. In practice, however, USGS field technicians add 0.20 ft (0.061 m) instead of 0.15 ft (0.046 m), a difference of 0.05 ft (0.015 m).

The circular base of the WSC aluminum winter rod is 0.045 m lower than the 0.0 mark, and this amount (0.045 m) must be added to the depth indicated by the calibration marks at every sounding. In practice, however, it was noted (based on a limited informal survey) that the calculation of this specific distance on the WSC winter rod may vary from one WSC hydrometric technician to another. This factor could be causing an underestimation of the total depth by WSC. This distance is in the order of the difference in depth observed. It is to be mentally added to the measured depth of water by the field technician. The distance is not specified or mentioned in either the Canadian or American National Standards on hydrometric practices. Therefore to ensure consistency, this distance should be specified in the National Standards of both countries, and in practice added to the depth indicated by the graduation marks.

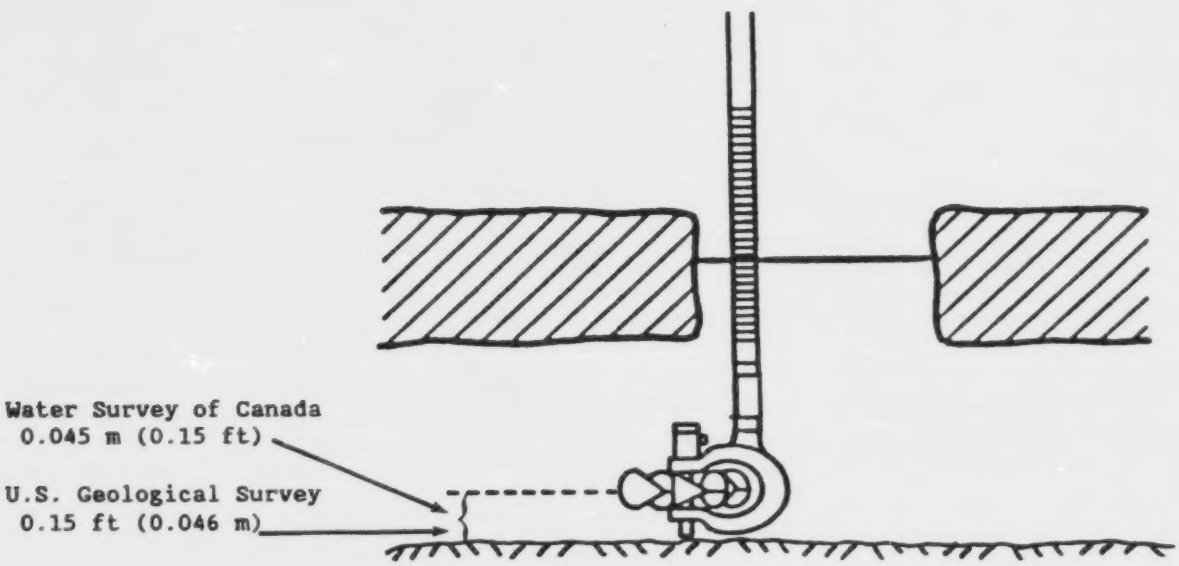


Figure 16. Winter rod set.

The winter rod base or foot available for the WSC winter rod, was not used by Water Survey of Canada technicians. However, the use of the winter rod base or foot should be promoted as it offers several advantages. This base protects the winter current meter by preventing contact with river bed materials. A horizontal projection at the top of the winter rod base protects the current meter from damage when it is raised through the ice cover. This horizontal projection is also used for measuring the thickness of ice. Soundings with the winter rod set are read from calibrations marked on the body of the rod. Since the circular base of the winter rod is 0.1 m lower than the 0.0 mark on the rod, this amount (0.1 m) must be added to the depth indicated by the calibration marks at every soundings. To determine if the winter rod base or foot has any effect on the performance of the winter current meter, the complete equipment package should be calibrated.

Moreover, the distance between the bottom of the Winnipeg winter weight and the middle of the cups of the WSC winter meter is not fixed for all winter weights. These weights are custom-made by a private manufacturer. In the Water Survey of Canada Hydrometric Field Manual (Terzi, 1981), the distance is specified at 0.24 m. However, measurements were made on different winter weights, and the distance was found to vary between 0.24 and 0.30 m. During the field measurement program, a distance of 0.30 m was used. Therefore, the WSC field manual should mention that the distance between the bottom of the winter weight and the middle of the cups is to be measured and added by the field technicians.

Table 18. Differences between USGS and WSC Depth Measurements

Date of Measurement	Meas. No.	Crew	Mean Difference* (m)	Standard Deviation (m)	Maximum Difference (m)	Minimum Difference (m)
86-01-21	1	WSC1	0.033	0.025	0.090	-0.020
86-01-21	2	WSC1	0.000+	-	-	-
86-01-22	1	WSC1	0.033	0.026	0.075	-0.027
86-01-22	2	WSC1	0.031	0.033	0.123	-0.042
86-01-23	1	WSC1	0.024	0.027	0.092	-0.042
86-01-23	1	WSC2	0.039	0.033	0.143	-0.002
86-01-23	2	WSC1	0.040	0.035	0.153	-0.008
86-01-23	2	WSC2	0.033	0.034	0.143	-0.008

$$\text{*Mean difference (m)} = \frac{\sum_{i=1}^{NV} DD}{NV}$$

where NV = number of verticals (excluding the water edges)
DD = the difference in observed depth between USGS and WSC
DD = (USGS - WSC1) or DD = (USGS - WSC2)

+ Used same depth (standard soundings).

4.2 Effect of Suspension

In previous sections it was shown that differences in discharge values measured by the USGS and WSC are largely caused by differences in velocities, because differences in the cross-sectional area were of the order of only 1% to 2%. They range from 1% to 15% (Table 17), depending on the type of equipment used. This difference is positive, meaning that the USGS measures higher velocities than WSC.

If the equipment used by the USGS and WSC consists of a meter on a rod suspension, the difference in mean velocity ranges from 1% to 5%. This combination of equipment was used by the USGS and WSC1 throughout the measurement program, and by WSC2 on January 21 and 22. However, when the equipment used by WSC2 consisted of a meter on cable suspension (weight-cable-reel) with the Winnipeg winter weight assembly, the difference in mean velocity significantly increases to +15%. To determine the reasons for these differences, several analyses were performed.

First, the velocity profiles were compared and analyzed for each measurement. It was determined that the velocities, as observed with a Price meter on cable suspension at 0.2 and 0.8 depth, are much lower than velocities observed with a Price or Vane meter on rod suspension (Table 8). Also, the difference at 0.8 depth, i.e. at lower velocities, is much higher than that at 0.2 depth. Moreover, the velocities at 0.2 and 0.8 depth are usually lower when observed with a Price meter on a rod suspension compared with a Vane meter on a rod. These facts are illustrated in Figures 17 to 19, where the velocity is plotted against the horizontal distance from an initial point in the cross section. The differences in velocities are summarized in Table 19.

In summary, from this preliminary analysis, it was determined that the velocities, as observed with a Price meter on cable suspension (standard equipment at this site), yielded lower velocities. It was also found that velocities observed with a Vane meter on rod suspension are systematically higher than velocities observed with a Price meter on rod suspension. Also, it appears that as the velocities decrease, the differences increase.

To determine the effect of suspension, the meters and suspension equipment were sent for calibration at the National Calibration Services in Canada (CCIW) and in the United States (HIF). The calibration tests were carried out with a meter on rod suspension and on cable suspension. The results of these tests are presented in Section 4.3. To demonstrate the effect of cable suspension, however, some results will be presented here.

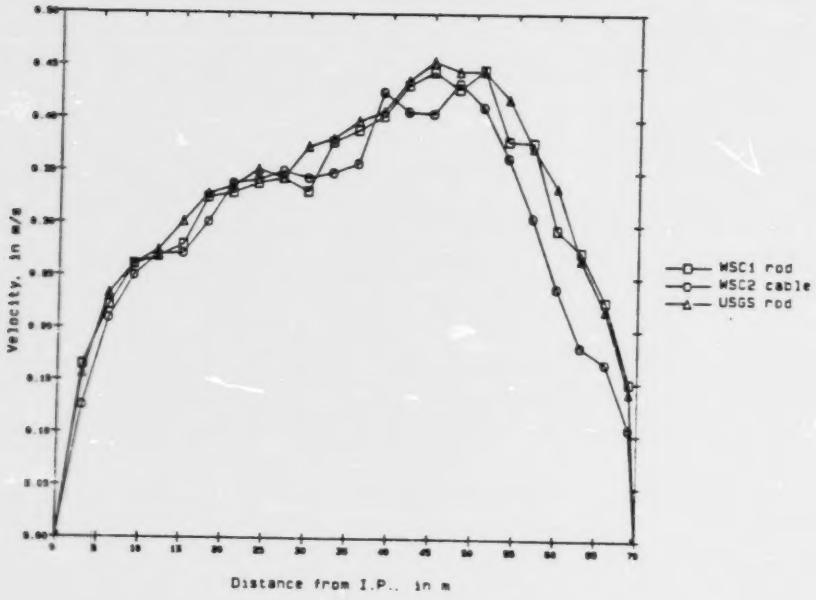


Figure 17. Velocity profile at 0.2 depth on the Red River at Emerson (January 23, 1986).

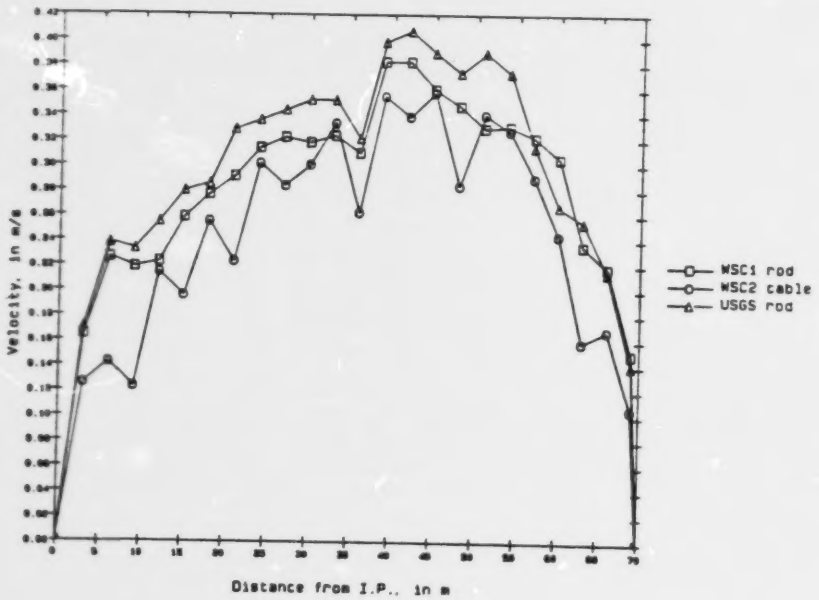


Figure 18. Velocity profile at 0.8 depth on the Red River at Emerson (January 23, 1986).

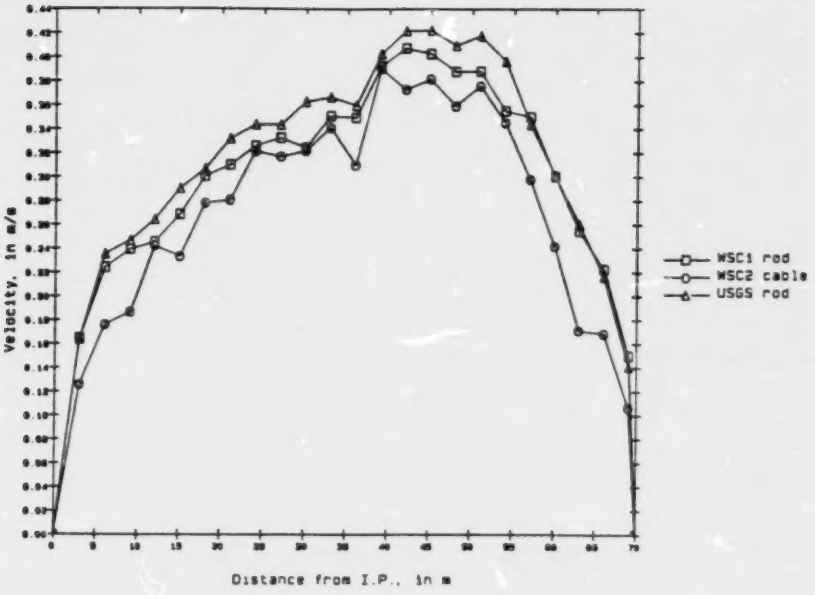


Figure 19. Mean velocity profile on the Red River at Emerson (January 23, 1986).

Table 19. Differences between USGS and WSC Velocity Observations

Date of Measurement	Meas. No.	WSC Crew	Suspension	Mean* Velocity Ratios at 0.2-d	Mean Velocity Ratios at 0.8-d	Mean Velocity Ratios
86-01-21	1	WSC1	Rod	1.008	1.009	1.007
86-01-21	2	WSC1	Rod	1.007	1.038	1.021
86-01-22	1	WSC1	Rod	0.990	1.045	1.014
86-01-22	2	WSC1	Rod	0.987	1.061	1.019
86-01-23	1	WSC1	Rod	1.023	1.059	1.039
86-01-23	2	WSC1	Rod	1.016	1.025	1.020
86-01-23	1	WSC2	Cable	1.131	1.274	1.187
86-01-23	2	WSC2	Cable	1.168	1.247	1.202

*The difference is expressed as the mean ratio of the velocities and computed as follows:

$$\text{Mean velocity ratio} = \frac{\sum_{i=1}^{NV} R}{NV}$$

where NV = number of verticals (excluding the water edges)
and R = ratio of velocities (if R > 1, $V_{USGS} > V_{WSC}$)

$$R_{0.2d} = \frac{V_{0.2d}\ (USGS)}{V_{0.2d}\ (WSC)}$$

$$R_{0.8d} = \frac{V_{0.8d}\ (USGS)}{V_{0.8d}\ (WSC)}$$

$$R_{mv} = \frac{\frac{V_{0.2d} + V_{0.8d}}{2}\ (USGS)}{\frac{V_{0.2d} + V_{0.8d}}{2}\ (WSC)}$$

To determine the effect of the Winnipeg (NACA or "tear drop") winter weight assembly for the cable suspension on the rating for the WSC winter meter for the rod type suspension, the following procedure was used: (i) the meter alone was rated on rod suspension and then (ii) the combined meter and weight assembly was rated. Rating equations were derived for the WSC winter meter 6-288 on rod and on cable suspension. The meter suspension type combination was the very same unit as the one used in the field.

A comparison between current meter rating equations for the WSC winter meter 6-288 (developed at CCIW) was performed (Fig. 20). The relationship plotted is the velocity (V, m/s) versus the number of revolution(s) per second (N, rev/s). The slope of the rating equation for WSC meter 6-288 rated on cable suspension is much higher than the slope for WSC meter 6-288 rated on rod suspension. This indicates the need for a separate rating equation.

The results were also compared by computing correction coefficients, which are the velocity ratios (for specific meter rotor speeds) for the meter and weight assembly rating divided by the meter and rod rating. The results are plotted in Figure 21. The correction coefficient should be applied to the rod rating to develop a cable suspension rating. Note that correction coefficients for field use should be based on a larger test sample, say, N = 10 for each speed to determine the variance in the values.

From Figure 21, the correction coefficient can be seen to range from 1.171 at 0.1 m/s to 1.044 at 0.5 m/s. These results indicate that the meter rotates approximately 4% to 17% slower when mounted with the NACA winter weight assembly than when mounted by itself on a rod. The correction curve in Figure 21 also shows that the correction coefficient varies with velocity (or number of revolution(s) per second).

Using the rating equations developed for the current meter on cable suspension, the discharge measurements were computed. The computed flow is 8.3% higher than the discharge computed using the current meter equation rated on rod suspension but used on cable suspension.

The effect of cable suspension has been studied previously. As early as 1904, Murphy reported similar conclusions in a study on the accuracy of stream measurements. A small Price meter was rated on a rod and on a cable and weight assembly (18-lb sinker).

Based on Murphy's results, correction coefficients were computed for comparison purposes, and a correction curve prepared (Fig. 22). The correction coefficient is seen to range from 1.091 m at 0.12 m/s to 1.010 at 0.51 m/s. Murphy concluded by stating that each case (rod versus cable) requires a separate rating.

Schneider and Futrell II (1984) evaluated the performance of two ice meters (Vane and WSC winter) and three winter weight assemblies (Vane ice meter, Pancake, and Slush-n-all) in a towing tank. Each meter was first rated individually on a rod suspension and then again on a cable suspension, with

the appropriate weight assembly. The effect of the weight assembly on the rod suspension for each meter was derived by computing a correction coefficient which varied between 0.88 and 1.10, depending on the weight assembly and velocity. The correction curves developed for the WSC winter meter and weights are presented in Figure 23.

Schneider and Futrell II (1984) stated that the velocities measured with all the meters on cable suspension require correction if the meters have been rated on a rod.

Chapman (1968) conducted a rating program in Canada to establish the relationships of the ratings of the 622 pattern type AA Price current meter using different Columbus weight sizes and suspension systems. He concluded that if suspension methods other than the standard suspension and weight (30 lb) are used in the field, a correction coefficient would improve the degree of accuracy. Chapman recommended that special ratings should be requested if a number of measurements are to be taken using suspension methods other than the 30-lb Columbus weight.

The effect of Columbus type sounding weights (15 lb, 30 lb, 50 lb and 100 lb) on the performance of the Price current meter was also investigated by Engel and DeZeeuw (1984b) of the National Water Research Institute. The 75-lb Columbus weight is also used by WSC but was not included in their investigation. They concluded that

(a) The response curve obtained with the 30-lb standard suspension is very similar to that obtained when the meter is attached to a rod suspension.

(b) The response curves obtained with the 15-lb, 50-lb and 100-lb standard suspension differ significantly from those obtained when the meter is attached to a rod suspension.

They also ranked the four standard sounding weight suspensions in order of suitability for a good calibration, i.e., 100 lb, 30 lb, 50 lb and 15 lb. Calibration suitability is defined in terms of the responsiveness (N/V in revolutions per metre) of the current meter.

At the same time, Engel and DeZeeuw made the following recommendations:

(a) A calibration provided with a 15-lb, 30-lb, 50-lb, and 100-lb standard sounding weight suspension should not be used with the meter in either of the two other possible positions on the WR2 hanger for each of the sounding weight sizes.

(b) A calibration provided with each of the 15-lb, 30-lb, 50-lb, and 100-lb standard sounding weight suspensions should not be used with any of the other three standard suspensions.

They also noted that failure to observe these recommendations could result in measurement errors of several percent (approximately 7% at 0.2 m/s) in many cases and errors exceeding $\pm$0.5% in virtually all cases. Finally, they recommended that the Price AA meter always be calibrated with the same suspension configuration in which it is to be used.

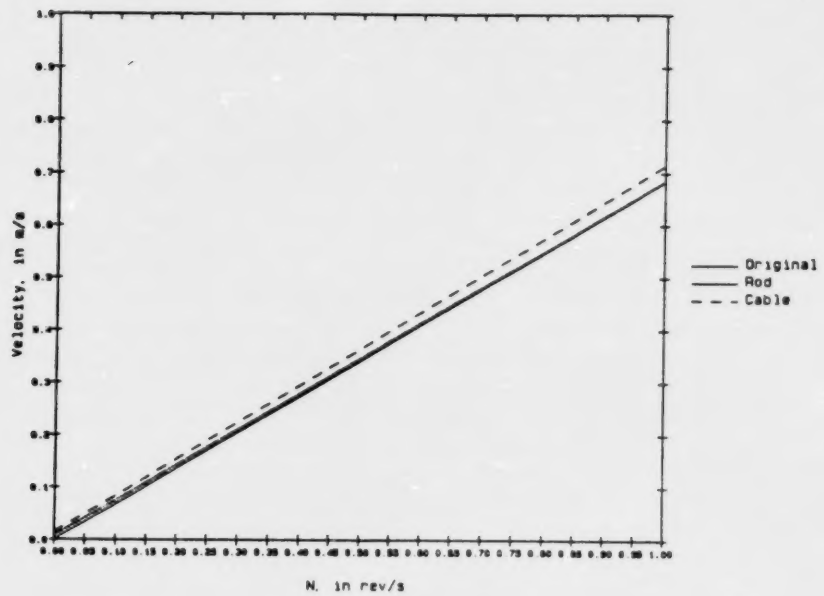


Figure 20. Comparison of current meter rating equations for the WSC winter meter 6-288 (CCIW February calibration) on rod and cable (with NACA) suspension.

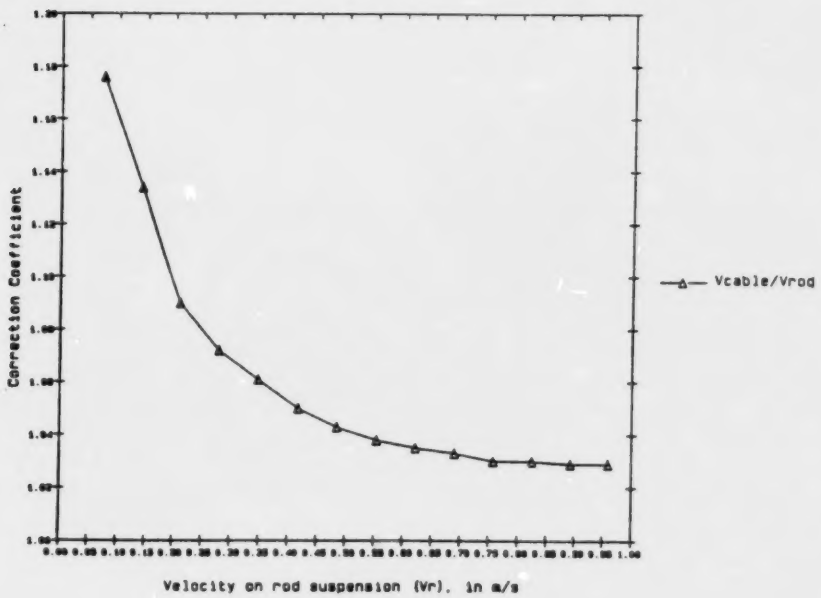


Figure 21. Correction curve required to convert rigid rod rating to cable rating (with NACA), WSC winter meter 6-288 (CCIW February calibration).

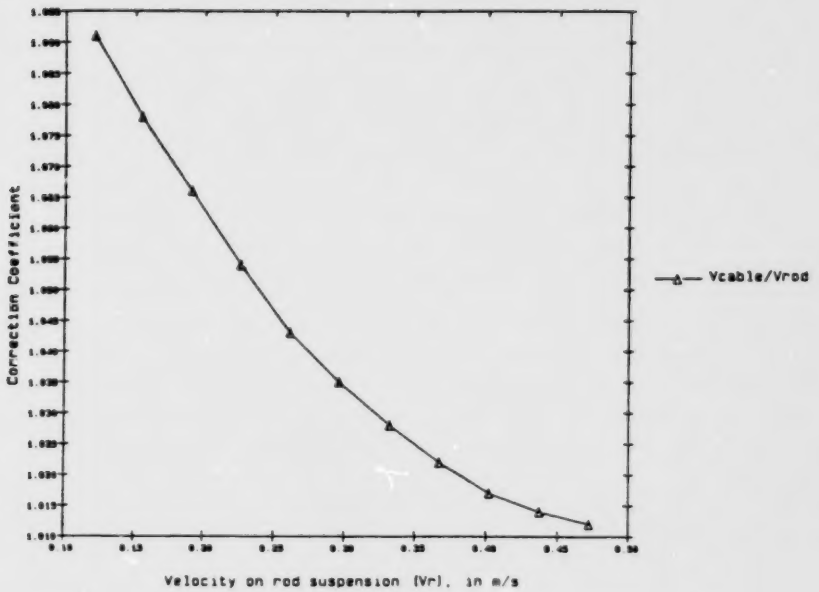


Figure 22. Correction curves from Murphy (1904) investigation.

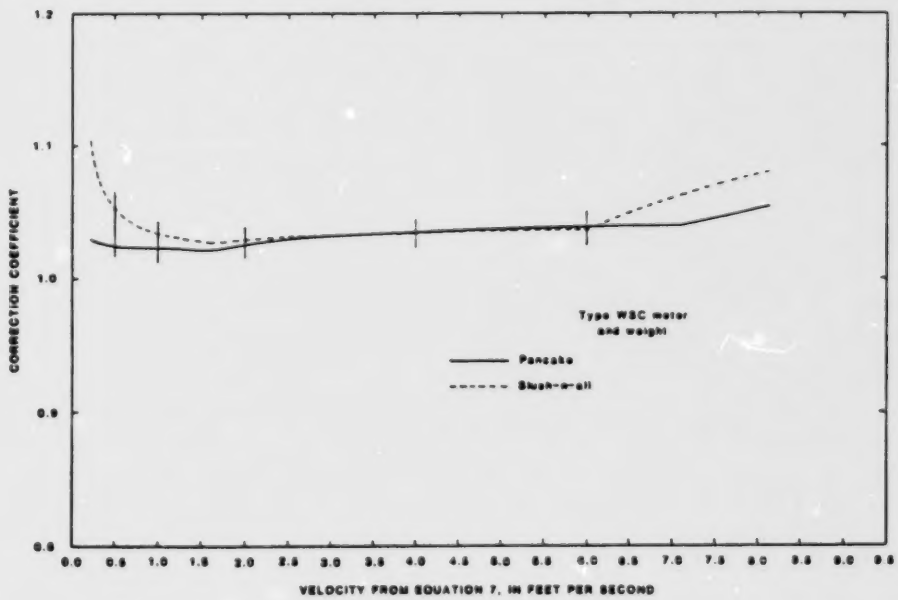


Figure 23. Correction curves from Schneider and Futrell II (1984) investigation.

Chow (1964) also mentioned that if a current meter is rated on rod suspension but used on cable suspension with Columbus weights, the average velocity for the measurement should be corrected by a coefficient that is a function of the method of suspension (15 lb, 30 lb, 50 lb, 75 lb or 100 lb) and the velocity. The suspension coefficients suggested by Chow range from 0.99 and 1.02.

The effect of cable suspension has also been reported by ISO 2537 (1974), ISO 3455 (1976), and Herschy (1978, 1985).

A new polymer rotor has been developed by both agencies for use with the standard Price meter yoke. This meter might be used in the future to measure discharge under ice conditions. Therefore, the effect of cable suspension on the polymer rotor cup type meter will now be described. The following analysis is based on a restricted number of calibrations.

In recent years, the U.S. Geological Survey has introduced a plastic rotor for the measurement of streamflow under winter conditions to prevent ice from adhering to the rotor. Apart from the material making up the rotor, the major difference between the traditional Price meter and plastic rotor meter is that the conical elements of the rotor are solid versus the metallic rotor, which has empty conical elements.

Engel and DeZeeuw (1984a) reported that the USGS plastic rotor could provide considerable improvement in measuring low velocities. Moreover, Engel et al. (1985) reported that the performance of the USGS plastic rotor could be significantly improved by prudent changes to the rotor geometry. With streamlined noses on the rotor elements, the linearity of the rotor low speed response increases. They also reported that composite rating equations would be necessary. Engel et al. (1985) found that the rate of rotation of the rotor would increase, by approximately 4%, if depressions in the bases of the conical rotor also were made. Their preliminary results indicated that threshold velocities of less than 2 cm/s could be obtained.

The USGS plastic rotor or its modified version may be better suited for the measurement of discharge under winter conditions. Several advantages of such meters are no slush accumulation, possibly standard rating, and low cost.

The original plastic rotor meter (EXP-1) was calibrated at the National Calibration Service (NWRI in Canada) in January 1985. The meter was rated on rod and cable suspension. The weight assemblies included a Pancake, Slush-n-all, and NACA.

A comparison between current meter rating equations for the EXP-1 plastic rotor (developed by CCIW) was performed. This comparison is illustrated in Figure 24. The relationship plotted is the velocity (V, m/s) versus the number of revolution(s) per second (N, rev/s).

The slope of the rating equation for EXP-1 meter rated on cable suspension, with either the Pancake, NACA or Slush-n-all weight assembly, is much higher than the slope for the EXP-1 meter rated on rod suspension. Again, the need for separate rating equations is indicated.

Results were also compared by computing correction coefficients, which are the velocity ratios (for specific meter rotor speeds) for the meter with weight assembly rating divided by the meter with rod rating. The results are plotted in Figure 25. The correction coefficient would be applied to the rod rating to develop a cable suspension rating.

From Figure 25, the correction coefficient can be seen to range from 1.07 to 1.10 at 0.3 m/s and from 1.02 to 1.08 at 0.5 m/s, depending on the weight assembly used. These results indicate that the meter rotates approximately 2% to 10% slower (between 0.3 and 0.5 m/s) when mounted with a winter weight assembly than when mounted by itself on a rod. The correction curve in Figure 25 also shows that the correction coefficient varies with velocity (or number of revolution(s) per second).

The weight assembly, which appears to offer the most stable correction curve, through the velocity range, is the Pancake winter weight assembly, followed by the Slush-n-all. The lowest correction coefficients are obtained with the polymer meter attached to the NACA winter weight assembly.

In summary, the plastic rotor meter may offer a good alternative to the traditional metallic rotor meter. If the meter (metal or plastic) is rated on rod suspension but used in the field on cable suspension, however, a correction coefficient is required.

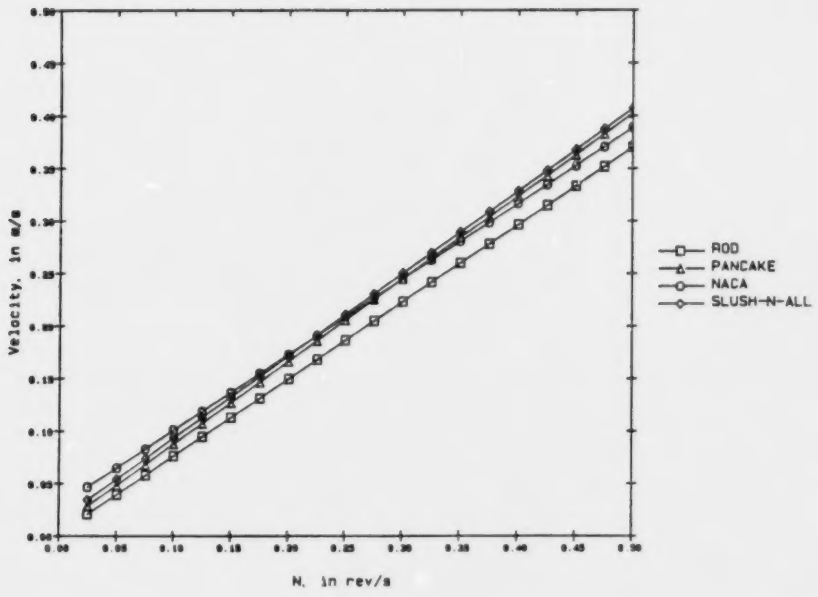


Figure 24. Comparison of rating equations for plastic rotor EXP-1 (CCIW, January 1985).

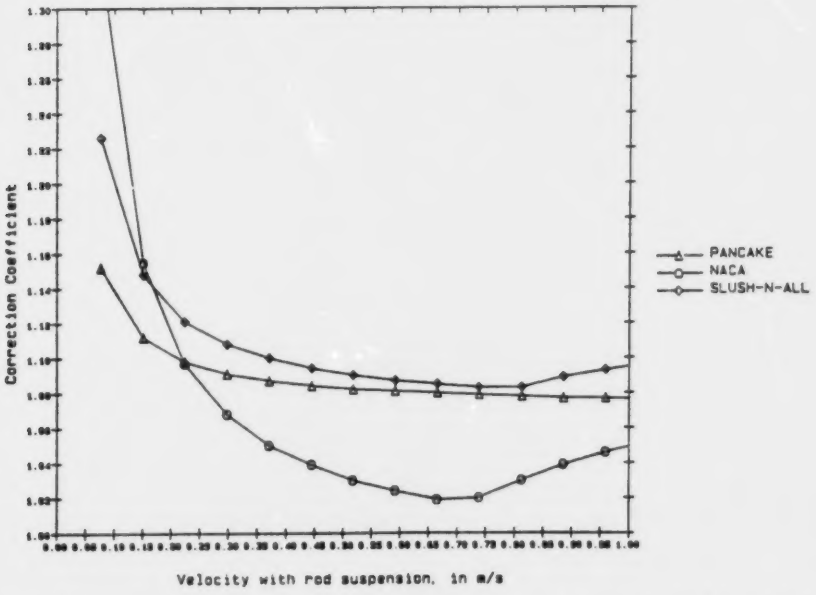


Figure 25. Correction curve required to convert rigid rod rating to cable rating for plastic rotor EXP-1 (CCIW, January 1985).

4.3 Effect of Current Meter Rating Procedures

The current meters (WSC winter meters 6-356 and 6-288, and the USGS Vane ice meter I-39) used in the January 1986 field experiments were calibrated at the Calibration Services in Canada and in the United States. The results of these tests were summarized in Section 3.2.1 (Tables 12 to 14). A comparison of the current meter rating equations was carried out and is presented here.

4.3.1 Effect on WSC Winter Meter 6-356

The comparison for the WSC winter meter 6-356 on rod suspension is presented in Figure 26. It shows the variability between the types of rating equations derived by the two agencies, expressed as correction coefficients which are the velocity ratios for the new rating equation divided by the original (old) rating equation.

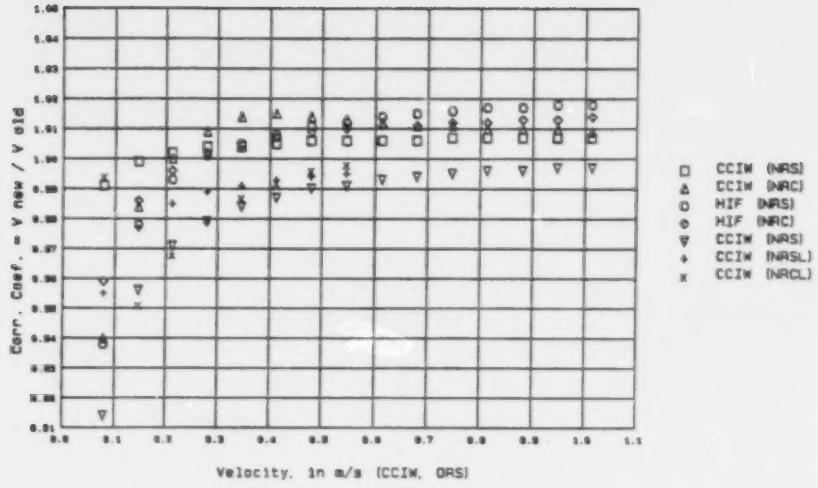
From Figure 26, the correction coefficient for meter 6-356 can be seen to range from 0.91 to 1.01 for velocities lower than 0.3 m/s and from 0.98 to 1.02 for velocities higher than 0.3 m/s. It may be recalled that the mean velocity of the Red River on January 22-23 was approximately 0.3 m/s.

Close examination reveals that there is a difference between rating equations developed by the two agencies of approximately 1% and a difference between single and composite ratings of approximately 1%. However, the differences increase as the velocities decrease below 0.3 m/s. The number of runs or tests and the range of selected velocities used to calibrate a specific current meter may explain part of the departure of the measured points.

The calibration data for WSC winter meter 6-356, as derived in February 1986, are presented in Figure 27. The relationship plotted is the velocity (V) versus the number of revolutions (N). The single and composite equation, for $N < 0.60$ rev/s, plotted in Figure 27, indicates that a composite rating may provide more accurate low velocity determination. In fact, the differences between the composite and single rating range from 10% at 0.04 m/s to 1% at 0.3 m/s.

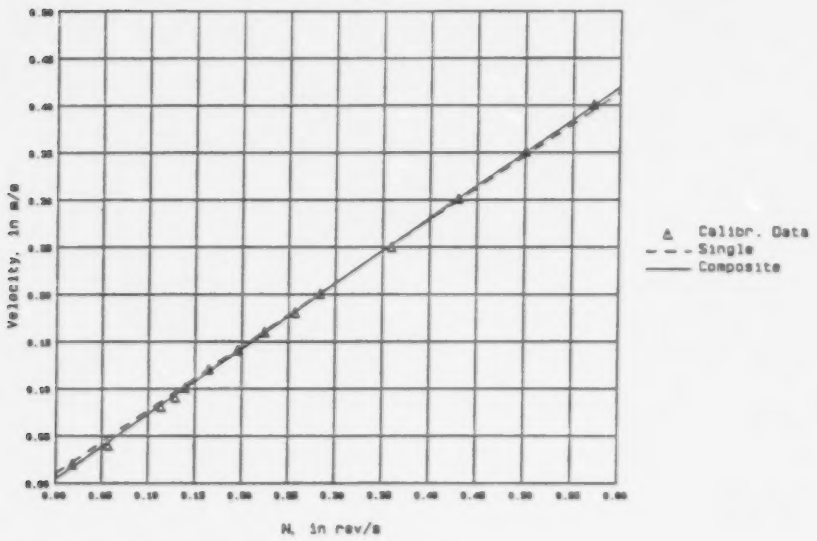
The analysis of the residuals, i.e., difference between true velocity (i.e. calibration data) minus single rating velocity and true velocity minus composite rating velocity, did indicate a pattern in the residuals (Fig. 28). The amplitude of the pattern is relatively small. An improvement in the rating equation could possibly be made using polynomial (2nd and 3rd degree), hyperbolic, or elliptic regression equations instead of linear equations. The analysis also confirmed the lower residuals when using a composite rating.

Finally, the correlation coefficients (r) between true velocity and velocity using single and composite ratings were computed and found to be very close to 1.0 (i.e. 0.999 98 versus 0.999 99).



Notes:
ORS - Old Single Rating
NRS - New Single Rating
NRC - New Composite Rating
NRSL - New Single Rating, Low Velocity Range

Figure 26. Comparison of current meter equations for WSC winter meter 6-356.



NOTE: EQUATION DERIVED BY C.C.I.W. (FEBRUARY, 1986)
COMPOSITE EQUATION VALID FOR N < 0.564

Figure 27. Calibration data for WSC winter meter 6-356 on rod.

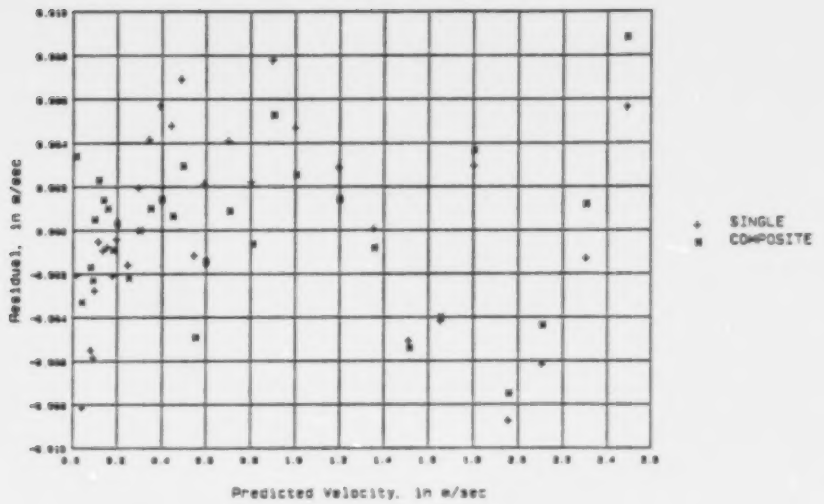


Figure 28. Residual versus predicted velocity (WSC 6-356).

4.3.2 Effect on WSC Winter Meter 6-288

The comparison between current meter equations for the WSC winter meter 6-288 on rod suspension is presented in Figure 29. The correction coefficient can be seen to range from 1.02 to 1.18 for velocities lower than 0.3 m/s and from 1.00 to 1.03 for velocities higher than 0.3 m/s.

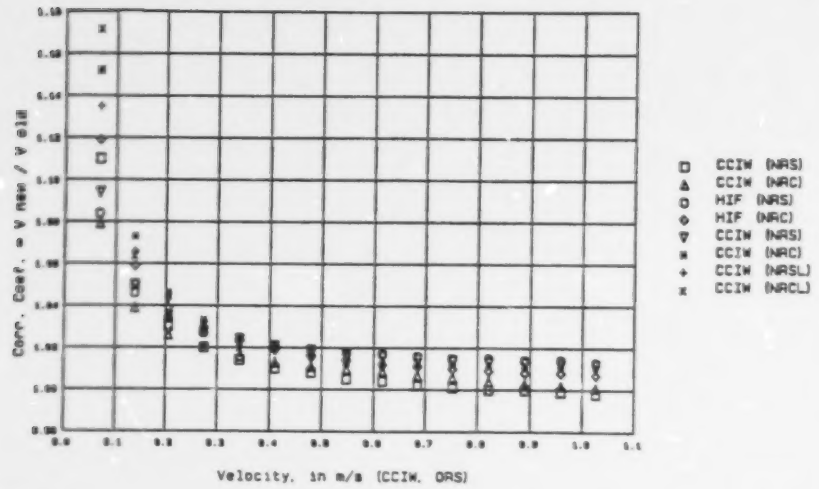
These results indicate differences in the order of 1% between single and composite ratings and between Canadian and American ratings. These differences increase as the velocities decrease below 0.3 m/s. The results are similar to those of the WSC meter 6-356.

The comparison of the current meter rating equations for the WSC winter meter 6-288 on cable suspension is presented in Figure 30. The correction coefficient can be seen to vary from 0.80 to 1.30 for velocities lower than 0.50 m/s and from 1.00 to 1.05 for velocities higher than 0.50 m/s. The reasons for the very large correction coefficients required to convert a rod rating to a cable rating were outlined in Section 4.2.

The differences between rating equations, as developed by the two agencies for the WSC winter meter 6-288 on cable suspension, are approximately 12% at velocity equal to 0.1 m/s, 4% at 0.3 m/s, and 2% at 0.5 m/s. They are significantly higher than for the rod suspension. In fact, analysis of the cable suspension calibration data indicates that it might be more difficult to repeat a good calibration when using cable suspension.

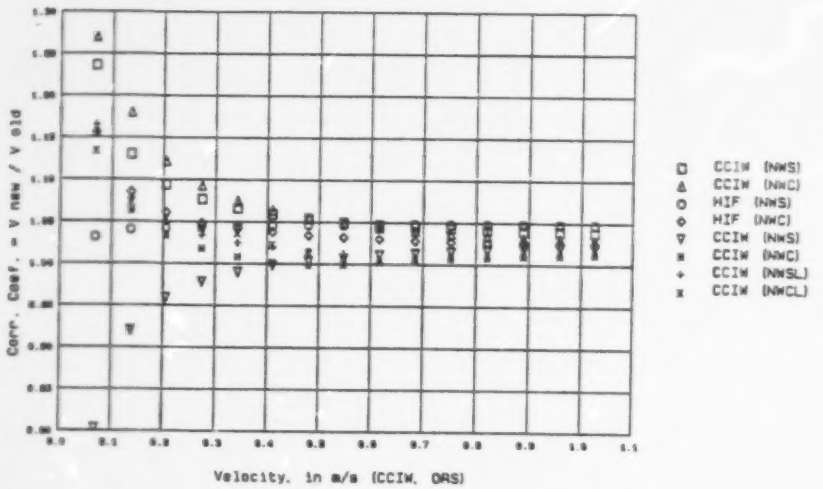
Engel and DeZeeuw (1984b) made similar observations and found that the standard sounding weight suspensions used by Water Survey of Canada may be ranked in order of suitability for a good calibration, i.e., 100-lb, 30-lb, 50-lb and 15-lb standard suspension. It is interesting to note that the least suitable sounding weight for good calibration is the 15 lb, which is comparable in weight only (not in shape) to the NACA weight.

The difference between single and composite rating equations at 0.3 m/s is approximately 1% and as much as 7% at 0.1 m/s.



Notes:
ORS - Old Single Rating
NRS - New Single Rating
NRC - New Composite Rating
NRSL - New Single Rating, Low Velocity Range

Figure 29. Comparison of rating equations for the WSC winter meter 6-288 on rod suspension.



Notes:
ORS - Old Single Rating on Rod Suspension
NWS - New Single Rating on Cable Suspension
NWC - New Composite Rating on Cable Suspension
NWSL - New Single Rating on Cab. Susp., Low Vel.

Figure 30. Comparison of rating equations for the WSC winter meter 6-288 on cable suspension.

4.3.3 Effect on USGS Vane Ice Meter I-39

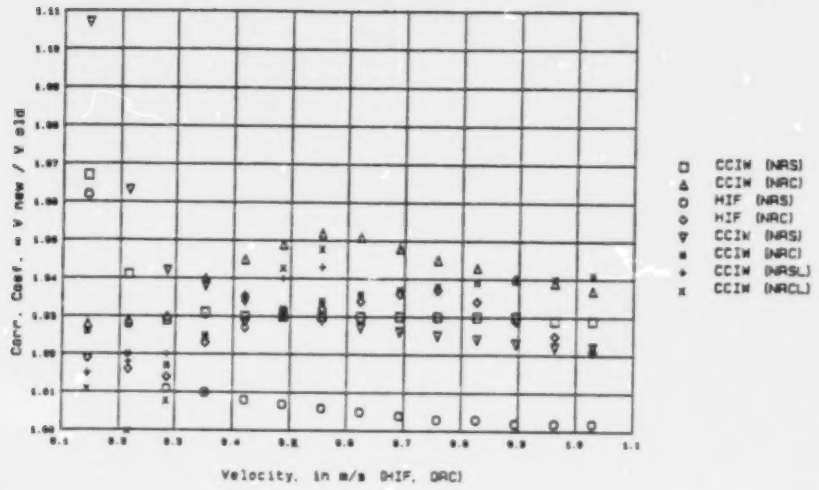
The comparison for the USGS Vane meter I-39 on rod suspension is presented in Figure 31. For velocities higher than 0.3 m/s, the correction coefficient (the coefficient required to convert the original composite (old) rating to the new rating) is seen to range from 1.02 to 1.05, except for the single ratings derived by the USGS, which vary from 1.00 to 1.01. For velocities lower than 0.3 m/s, the coefficients vary from 1.00 to 1.11.

These results indicate that there is a difference between single (NRS) and composite (NRC) ratings of approximately 2%, and a difference between equations developed by Canada and the United States for the same meter of approximately 2%. These differences increase significantly as the velocity decreases below 0.3 m/s.

The February 1986 calibration data for the USGS Vane meter I-39 are presented on Figure 32. The single and composite equation for $N < 0.857$ rev/s plotted in Figure 32 indicates that a composite rating may be as much as 18% more accurate at 0.04 m/s and 1% at a velocity of 0.25 m/s.

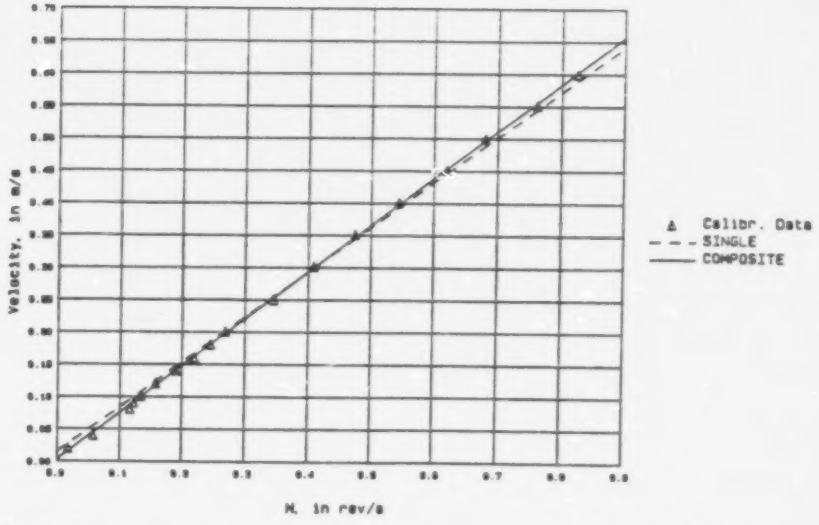
The analysis of the residuals (Fig. 33) indicated that the residuals for a single rating followed a pattern. A pattern was also observed for the composite rating, but of much less amplitude. This observation indicates the need of a composite rating for a Vane meter. Moreover, it was observed that the residuals are significantly lower for the composite equations.

The correlation coefficients (r) between true velocity and velocity using a single and composite equations were computed and found to be close to 1.0 (i.e. 0.999 94 and 0.999 99).



Notes:
ORC - Old Composite Rating
NRS - New Single Rating
NRC - New Composite Rating
NRSL - New Single Rating, Low Velocity Range

Figure 31. Comparison of rating equations for USGS Vane ice meter I-39.



Notes:
Equation derived by C.C.I.W. (February, 1986)
Composite rating valid for N < 0.857

Figure 32. Calibration data for USGS Vane ice meter I-39 on rod suspension.

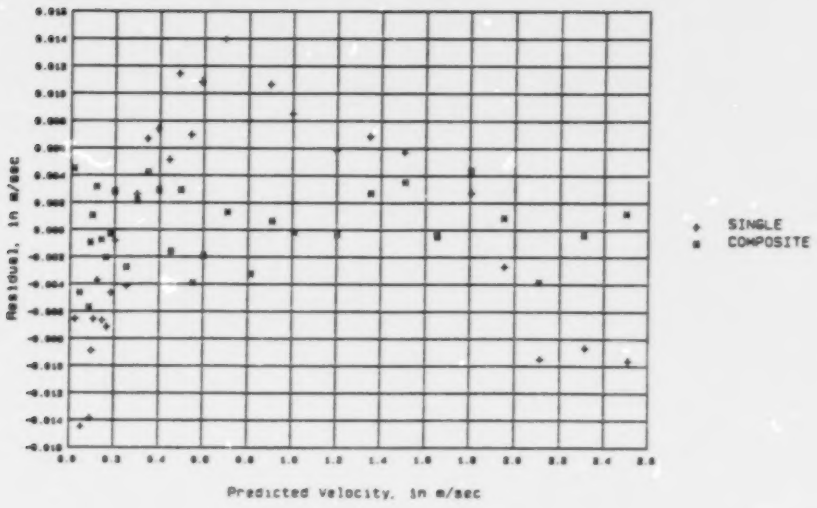


Figure 33. Residual versus predicted velocity (USGS I-39).

4.3.4 Effect on Discharge Measurements

The analysis of the calibration data for the USGS Vane ice meter and WSC winter meter on rod suspension indicates the following:

(i) The variability between current meter rating equations, as derived by Canada and the United States, is higher for the Vane type than for the cup type. In other words, the repeatability of current meter ratings appears to be superior for the cup type.

(ii) The differences between single and composite equations are larger for the Vane meter when compared with the WSC winter meters. The analysis of the residuals indicated that a composite rating is definitely more appropriate for the Vane meter, and that a composite might provide additional accuracy at low velocities for the WSC winter meter.

(iii) The correction coefficients are generally higher for the Vane meter when compared with the WSC meter. The Vane meter was last rated in 1976 (for velocities higher than 0.3 m/s) and in 1981 (for velocities less than 0.3 m/s), while the WSC meters were rated in 1984 and never used in the field prior to the 1986 metering program.

(iv) The number of tests or runs used to calibrate a Vane or cup-type current meter appears to be a significant factor in the representativeness of the rating equation. The U.S. Geological Survey determined their current meter rating by towing the meter at ten different speeds, in both direction (backwards and forwards), for a total of 20 points. However, Water Survey of Canada determined their current meter rating by towing the meter at 20 different speeds.

The differences between the Vane type and cup type meters will be further analyzed and discussed in Section 4.4.

The analysis of the calibration data for WSC winter meter 6-288 on cable suspension indicates the following:

(i) If a meter is to be used on cable suspension with weight assembly in the field it should be rated accordingly in the laboratory. Further investigation into the rating of the current meter on cable suspension is required.

(ii) A composite rating is required when a meter is rated on cable suspension. In fact, the rating may comprise two or more equations or a more sophisticated mathematical function, such as polynomial of degree 3.

(iii) The differences between Canadian and American ratings are considerably higher than when the meter is rated on rod suspension. In other words, the repeatability of the calibration tests on cable suspension does not appear to be as good as for the rod suspension tests, even when using the same weight for each meter.

A comparison of discharges using the current meter rating equations derived by CCIW in February 1986 and by HIF in March 1986 was performed. The discharge comparison using the new equations is presented in Tables 20 to 22 for the field measurements collected on January 21, 22, and 23, 1986, respectively. The discharge ratios, which are the discharges measured by the USGS divided by the discharges measured by WSC1 or WSC2, were computed using composite ratings derived by CCIW and by HIF on the appropriate suspension type. This comparison (Table 23) yielded the following observations:

(1) USGS discharge measurements that were initially higher than those of WSC1 (WSC 6-356, on rod) by 2% to 6% are 4% to 9% higher if computed with CCIW new rating equations, and 6% to 10% higher if computed with HIF new ratings;

(2) USGS discharge measurements that were originally higher than those of WSC2 (WSC 6-288 on rod) by 4% to 6% are 5% to 7% higher if computed with CCIW new ratings, and 3% to 5% if calculated with HIF new current meter equations;

(3) USGS discharge measurements that were originally higher than those of WSC2 (WSC 6-288 on cable) by 15% to 17% are 11% to 12% higher using CCIW ratings, and 13% to 14% higher using HIF ratings.

Therefore, these results indicate that measurements taken by the USGS Vane ice meter mounted on rod suspension will generally be higher, by 0 to 10%, than those of the WSC winter meter on rod. Also, the effect on streamflow values of using new rating equations derived by Canada or by the United States is significant.

The discharge measurements obtained by the two Water Survey of Canada crews were also compared (Table 24) and provide some additional information such as:

(1) WSC1 (WSC 6-356 on rod) discharge measurements that were initially higher than those of WSC2 (WSC 6-288 on rod) by 0 to 4% are -1% to 3% lower or higher if calculated with CCIW new equations, and -5% to -1% lower if computed with HIF new ratings;

(2) WSC1 (WSC 6-356 on rod) discharge measurements that were originally higher than those of WSC2 (WSC 6-288 on cable) by 9% to 13% are 2% to 5% higher if computed with CCIW new equations, and 3% to 6% higher using HIF ratings.

Therefore these results indicate that measurements taken with WSC winter meters mounted on either rod or cable, but appropriately rated, will agree within 5%. Also, the effect on discharge values of using different current meter rating procedures (CCIW vs HIF) is significant.

Table 20. Comparison of Discharges Using Different Rating Equations, Red River at Drayton, January 21, 1986

Crew	Suspension	Meter	As originally computed		As re-rated on rod by			
			CCIW	HIF	CCIW		HIF	
			Qors	Qorc	Qnrs	Qnrc	Qnrs	Qnrc
Measurement No. 1								
WSC1	Rod	6-356	55.9	-	56.1	56.4	55.9	54.6
WSC2	Rod	6-288	53.7	-	54.9	54.8	55.2	55.3
USGS	Rod	I-39	-	57.1	58.9	58.9	57.9	58.0
Measurement No. 2								
WSC1	Rod	6-356	55.5	-	55.7	55.9	55.5	54.1
WSC2	Rod	6-288	54.5	-	55.6	55.6	56.0	56.1
USGS	Rod	I-39	-	56.7	58.5	58.4	57.5	57.6
Measurement No. 3								
WSC2	Rod	6-288	53.7	-	54.9	54.8	55.2	55.3

Note: Qors: discharge computed with original single rating on rod suspension.
Qorc: discharge computed with original composite rating on rod suspension.
Qnrs: discharge computed with new single rating on rod suspension.
Qnrc: discharge computed with new composite rating on rod suspension.

Table 21. Comparison of Discharges Using Different Rating Equations, Red River at Emerson, January 22, 1986

Crew	Suspension	Meter	As originally computed		As re-rated on rod by			
			CCIW	HIF	CCIW		HIF	
			Qors	Qorc	Qnrs	Qnrc	Qnrs	Qnrc
Measurement No. 1								
WSC1	Rod	6-356	56.1	-	56.3	56.8	56.3	55.1
WSC2	Rod	6-288	55.0	-	56.0	56.0	56.4	56.4
USGS	Rod	I-39	-	57.5	59.3	59.7	58.2	58.8
Measurement No. 2								
WSC1	Rod	6-356	55.4	-	55.7	56.1	55.7	54.5
WSC2	Rod	6-288	55.7	-	56.7	56.7	57.1	57.1
USGS	Rod	I-39	-	58.3	60.1	60.6	59.0	59.6

Note: Qors: discharge computed with original single rating on rod suspension.
Qorc: discharge computed with original composite rating on rod suspension.
Qnrs: discharge computed with new single rating on rod suspension.
Qnrc: discharge computed with new composite rating on rod suspension.

Table 22. Comparison of Discharges Using Different Rating Equations, Red River at Emerson, January 23, 1986

Crew	Suspension	Meter	As originally computed		As re-rated on rod and on cable by							
			CCIW	HIF	CCIW		CCIW		HIF		HIF	
			Qors	Qorc	Qnrs	Qnrc	Qnws	Qnwc	Qnrs	Qnrc	Qnws	Qnwc
Measurement No. 1												
WSC1	Rod	6-356	56.5	–	56.8	57.2	–	–	56.8	55.6	–	–
WSC2	Cable	6-288	51.8	–	52.8	52.7	55.5	56.1	53.1	53.2	54.2	54.2
USGS	Rod	I-39	–	59.8	61.6	62.2	–	–	60.5	61.2	–	–
Measurement No. 2												
WSC1	Rod	6-356	57.2	–	57.4	57.9	–	–	57.5	56.3	–	–
WSC2	Cable	6-288	50.8	–	51.7	51.8	54.5	55.2	52.1	52.2	53.1	53.2
USGS	Rod	I-39	–	59.4	61.2	61.7	–	–	60.0	60.7	–	–

Note: Qors: discharge computed with original single rating on rod suspension.
Qorc: discharge computed with original composite rating on rod suspension.
Qnrs: discharge computed with new single rating on rod suspension.
Qnrc: discharge computed with new composite rating on rod suspension.
Qnws: discharge computed with new single rating on cable suspension.
Qnwc: discharge computed with new composite rating on cable suspension.

Table 23. Discharge Rating Comparison between USGS and WSC1, WSC2

Date of Measurement	Measurement Number	Crew	Original* Discharge Ratios	CCIW+ Discharge Ratios	HIF++ Discharge Ratios
86-01-21	1	WSC1	1.021	1.044	1.062
86-01-21	2	WSC1	1.022	1.045	1.065
86-01-21	1	WSC2	1.063	1.075	1.049
86-01-21	2	WSC2	1.040	1.050	1.027
86-01-22	1	WSC1	1.025	1.051	1.067
86-01-22	2	WSC1	1.052	1.080	1.094
86-01-22	1	WSC2	1.045	1.066	1.043
86-01-22	2	WSC2	1.047	1.069	1.044
86-01-23	1	WSC1	1.058	1.087	1.101
86-01-23	2	WSC1	1.038	1.066	1.078
86-01-23	1	WSC2	1.154	1.109	1.129
86-01-23	2	WSC2	1.169	1.118	1.141

* Discharge Ratio = Q USGS / Q WSC1 or Q WSC2, from Tables 20 to 22.
+ Ratings derived at CCIW in February 1986.
++ Ratings derived at HIF in March 1986.

Table 24. Discharge Rating Comparison between WSC1 and WSC2

Date of Measurement	Measurement Number	Crew	Original* Discharge Ratios	CCIW+ Discharge Ratios	HIF++ Discharge Ratios
86-01-21	1	WSC2	1.041	1.029	0.987
86-01-21	2	WSC2	1.018	1.005	0.964
86-01-22	1	WSC2	1.020	1.014	0.977
86-01-22	2	WSC2	0.995	0.989	0.954
86-01-23	1	WSC2	1.091	1.020	1.026
86-01-23	2	WSC2	1.126	1.049	1.058

* Discharge Ratio = Q WSC1 / Q WSC2, from Tables 20 to 22.
+ Ratings derived at CCIW in February 1986.
++ Ratings derived at HIF in March 1986.

4.4 Effect of Current Meter Design

In previous sections it was shown that the Vane type current meter (USGS Vane ice meter) usually gives higher velocity than the cup type current meter (WSC winter meter). The difference between velocities observed by these two meters properly rated on rod suspension is usually less than 5%. Both meters are vertical axis meters, however, the USGS meter is made up of four vanes and the WSC meter has six cups.

The calibration of the WSC winter meter 6-356 and the USGS Vane ice meter I-39 at CCIW on February 1986 was done by attaching the meters to the towing carriage. The meters were then towed at different speeds, resulting in a total of 31 tests up to a maximum of 2.5 m/s. A test was defined as a tow of the meter with the towing carriage at a selected speed.

The calibration data are presented in Figure 34a as the number of rotor revolutions per second (N) versus the velocity (V). This relationship shows that the slope of the WSC winter meter is higher than that of the USGS Vane ice meter, indicating that the WSC winter meter is more sensitive. Meter sensitivity is defined as the change in rate of rotation (dN) over the change in rate of velocity (dV), i.e. dN/dV. For example, at velocities of 30.17 cm/s and 100.81 cm/s, the rate of rotation of the WSC winter meter 6-356 was 0.4300 rev/s and 1.4746 rev/s compared with 0.4085 rev/s and 1.4138 rev/s for the USGS Vane ice meter I-39. The slope of the WSC meter is then 1.48 versus 1.42 for the USGS meter, and thus the rate of rotation of the WSC meter is 6% higher than that of the USGS meter.

The same type of relationship (N versus V) is plotted in Figure 34b but for the March calibration at the U.S. Geological Survey Calibration Services. The slope for the cup type is higher than the Vane type in the lower velocities, although the difference is not as significant as for the February calibration.

The results tend to indicate that the cup type meter is more sensitive than the Vane type. However, further testing would be necessary to corroborate this observation.

The weight of each rotor tested was determined in air and water using standard procedures (Table 25). The dry weight of the USGS Vane ice rotor is about 13% more than the WSC winter rotor. However, the submerged weight of the USGS Vane ice rotor is about 18% less than the WSC winter rotor. Because the two meters do not have an identical design, it is impossible to draw conclusions at this point.

To determine which meter estimates the velocity of flowing water more precisely, they were tested in a 1-m flume. The calibration or testing of current meters under controlled conditions in a flume was assumed to be a practical way, and possibly the only way, to determine the precision and relative accuracy of a current meter.

The controlled conditions imply that the cross section is perfectly defined, including the position of the meter; the discharge flowing through the flume is precisely known and constant (within ±2%); and finally the testing is performed in a closed environment (no wind effect, etc.). The conditions would then warrant a fair comparison of the observed velocity using the USGS Vane and WSC winter meters to the "true" discharge.

The results of these tests were presented in Section 3.2.2 and summarized in Tables 15 and 16. The first series of tests (Table 15) consisted of recording the mean velocity as measured by each meter for six different depths. The mean velocity as recorded by the USGS Vane meter was usually higher (0 to 10%). These tests confirm the analysis of the field data, i.e., the USGS Vane meter is recording higher velocities than the WSC winter meter. However, the more accurate meter was still unknown. Therefore, additional testing was necessary.

The second series of tests (Table 16) included two flow measurements using five verticals and one velocity observation per vertical. The flume discharge was estimated using the volumetric method and was assumed to be the reference discharge ("true"). The first measurement, using the WSC 6-356, was 2.0% higher than the flume discharge compared with 4.5% higher using the USGS I-39. The second measurement, using the WSC 6-356, was 2.9% higher compared with 4.2% using the USGS I-39. The flume measurement comparison is presented in Table 26.

The results of the flow measurements in the flume also showed that the velocity distribution across the flume was generally symmetrical for the WSC winter meters, as would be expected, but asymmetrical for the USGS vane meter (Table 16 and Figure 35). It also indicates that if the current meters are placed in the center of the flume, where the velocity distribution was found to be uniform, all current meters responded identically. However, the response of the USGS vane meter is affected when it is moved near the wall (right) of the flume. This indicates that the USGS vane meter may be more affected than the WSC winter meter by a nonuniform velocity distribution across the meter and thus by turbulence.

In summary, this preliminary analysis of the current meter testing results in flowing water indicates that the WSC winter meter would give more accurate flow estimation when compared with the USGS Vane ice meter. However, it was shown in previous sections that if different rating equations were used, different results would be obtained.

Therefore, further testing is necessary to corroborate this observation. Tests in a 2-m flume would be more appropriate, and the rating of the winter meters under controlled ice cover conditions in a flume would be desirable.

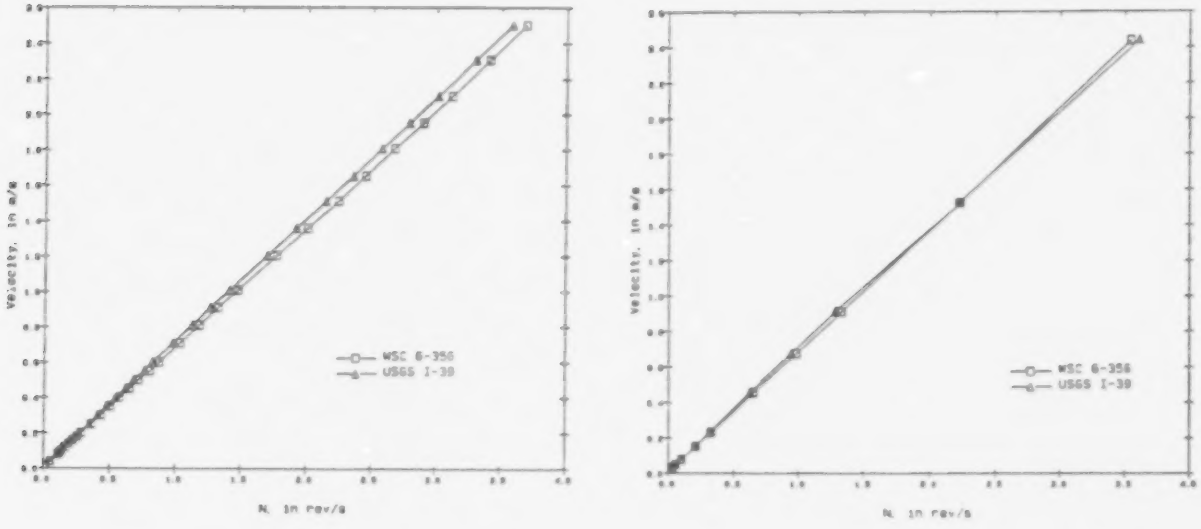


Figure 34. Comparison between Vane- and Cup-type current meter rating equations (a) February 1986, at CCIW; (b) March 1986, at HIF

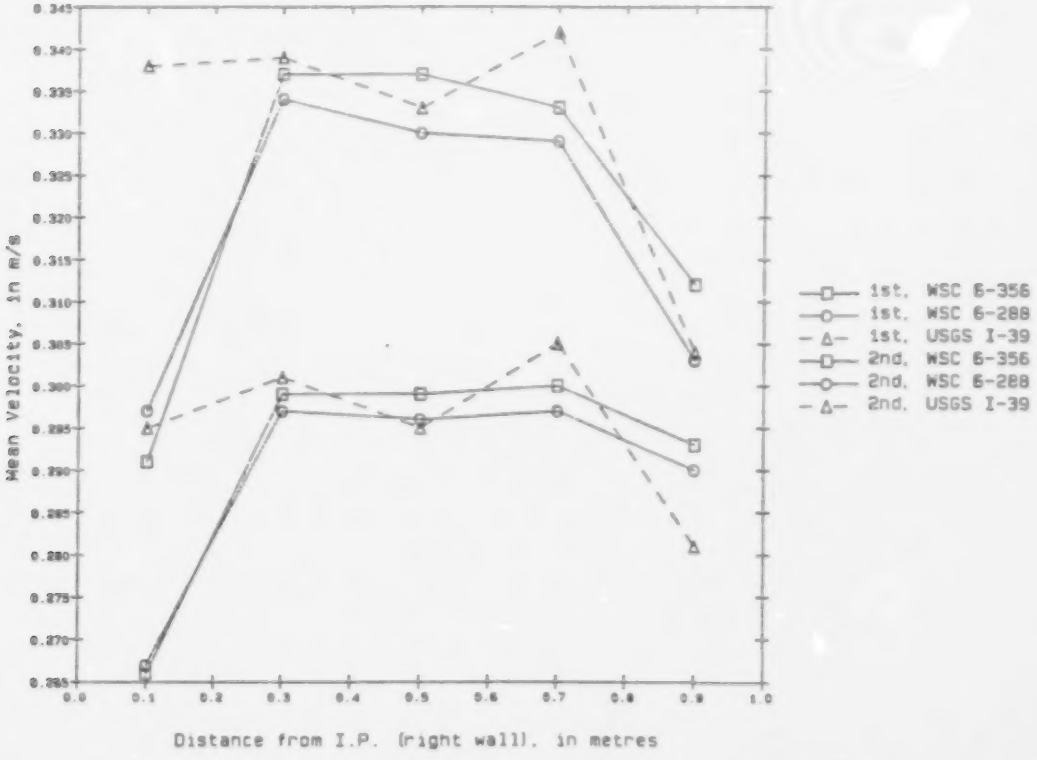


Figure 35. Velocity distribution in flume at CCIW

Table 25. Weights of Price and Vane Rotors in Air and Water

Meter	Weight in Air (g)	Weight in Water (g)
6-356 cup	150.43	132.22
6-288 cup	148.90	133.91
I-39 Vane	169.47	108.11

Note: Water temperature = +16°C.

Table 26. Flume Measurements Comparison

	1st Measurement*	Ratio+	2nd Measurement*	Ratio+
WSC 6-356 on rod	0.1302	1.020	0.1313	1.029
WSC 6-288 on rod	0.1287	1.009	0.1334	1.045
USGS I-39 on rod	0.1334	1.045	0.1329	1.042
Volumetric method	0.1276	1.000	0.1276	1.000

* Mean velocities were computed using February 1986 composite ratings (CCIW).

+ Ratio = $\frac{Q_{USGS\ or\ WSC}}{Q_{volumetric}}$

4.5 Effect of Limited Observations in the Vertical

Computation of the mean velocity in a vertical as an average or a weighted average of a number of point velocities results in an approximation of the true mean velocity in the vertical considered. This uncertainty is not due to pulsations but is related to the shape on the vertical velocity curve.

Due to the roughness of the underside of the ice cover the location of the filament of maximum velocity is some distance below the underside of the ice (Herschy, 1985). The velocity distribution under ice cover is similar to that in a pipe with a lower velocity near the underside of the ice (Fig. 36).

For both countries the 0.2 and 0.8 depth method is recommended for effective depths equal to or greater than 0.75 m (2.5 ft). For effective depths less than 0.75 m (2.5 ft), the 0.5 method is preferred in Canada and the 0.6 depth method, in the United States. A coefficient of 0.88 is used in conjunction with the 0.5 depth method and a coefficient of 0.92, with the 0.6 depth method. The USGS and WSC field procedures were discussed in Sections 2.2.2 and 2.2.3.

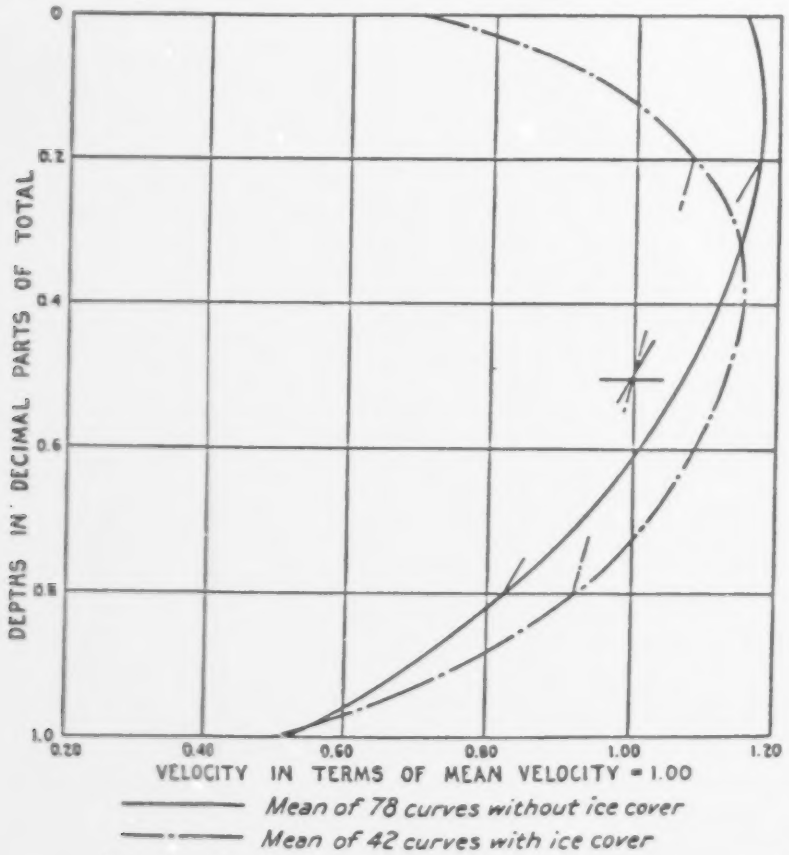


Figure 36. Typical vertical velocity curve under ice cover (after Barrows and Horton, 1907).

Standard procedures used in both countries for vertical velocity measurements under ice cover were developed from Barrows and Horton (1907). They analyzed over 400 velocity profiles from 25 gauging stations in five U.S. states (New York, Vermont, New Hampshire, Iowa and Ohio) and drew the following conclusions:

- "The average position of maximum velocity is at 0.37 depth below the ice, varying from 0.19 to 0.52 depth.

  In general, it becomes lower as the depth and velocity increase and hence as the stage increases. Rough ice cover tends also to lower the depth of the maximum thread....

  The average coefficient to apply for obtaining mean velocity from maximum velocity is 0.839, the variation being 0.76 to 0.90. This coefficient becomes less as the velocity increases, consequently its variation from the mean is not large for smooth ice. For rough ice it is considerably diminished and may reach a value of 0.75."

- "The average coefficient for obtaining the mean velocity from that at mid depth is 0.878, the range being from 0.82 to 0.92.

  The coefficient for obtaining mean velocity from that at mid depth becomes less for very rough ice, just as in the case of the maximum velocity, the average value for 13 curves being 0.82, with a range of from 0.76 to 0.85."

- "The average coefficient for obtaining mean velocity from the mean of the velocites at 0.2 and 0.8 depth is 1.002, the range being from 0.98 to 1.04....

  For very rough ice cover the mean value is 1.002, the range being from 1.00 to 1.04, indicating that rough ice tends to increase this coefficient slightly."

An average coefficient for obtaining mean velocity from that at 0.6 depth was not derived by Barrows and Horton.

Barrows and Horton (1907) recommended the following methods based on their analysis:

- "The cost of current meter measurements under ice cover can be kept within reasonable limits...by using the two-point method of observations at 0.2 and 0.8 depth, with a few vertical velocity curves, if possible, for purposes of study."

- "In case time is short a single observation at 0.5 depth will give fairly good results, the coefficient 0.88 being applied, or if a few vertical curves have been taken a better value of the coefficient can be determined from them."

- "Vertical velocity curves should be taken at typical points in the cross-section when time permits just as for open water. These should always be taken just before or after the two or one point observations at the point in question to give further information as to the field accuracy of these methods, the observations by the point method not being incorporated in the vertical velocity curve."

The requirement for sampling several vertical velocity curves (two or more) to determine the value of the coefficient necessary to convert the velocity obtained by the two- or one-point method to the mean velocity has been recommended or mentioned by several authors including Hoyt (1913), Corbett et al. (1957), Buchanan and Somers (1980), Rantz et al. (1982), and Herschy (1985). Although this procedure, i.e. sampling vertical velocity profiles, has been recommended, it is not considered a standard field procedure by either agency.

Using the k-e turbulence model, Lau (1982) calculated velocity distributions for channel flows with floating ice covers. He found that the velocities at 0.2 and 0.8 of the depth may deviate significantly from the overall average velocity. However, he noted that the differences seem to compensate for each other and that the average of these two velocities is about 2% higher than the actual mean velocity. If the velocity has to be measured at middepth, Lau found that the correction coefficient needed to obtain the mean velocity can be 5% larger or smaller than the value of 0.88 generally used.

Lau (1982) suggested a guide for a better correction coefficient based on the ice and bed roughness. For example, if the bed roughness is not too large and the ice seems relatively smooth, a correction coefficient of about 0.91 would be more appropriate. If both the river bed and the ice are very rough, a smaller value such as 0.84 would be better. However, the estimation of underside ice roughness may be impractical during hydrometric field surveys.

To determine the effect on the mean velocity of the number of points used in the vertical and also the differences between the Vane type and cup type meters, three vertical velocity profiles were taken on the Red River at Drayton (Table 5) and on the Red River at Emerson (Table 7). A comparison of these velocity profiles is presented in Figures 37 and 38. The vertical velocity curves as measured by the USGS Vane ice meter and WSC winter meter are very close for both locations.

At Drayton, the analysis of the data yielded the following observations: the average coefficient for obtaining mean velocity from the mean of the velocities at 0.2 and 0.8 depth is 1.000 using the WSC meter and 1.054 using the Vane meter. The average coefficient for obtaining the mean velocity from that at 0.5 is 0.946 using the WSC meter and 0.913 using the Vane meter versus the 0.88 standard. For 0.6 depth, the average coefficient for obtaining the mean velocity is 0.969 using the WSC meter, and 0.973 using the Vane meter versus the 0.92 standard.

At Emerson, the following results were obtained: the average coefficient for obtaining mean velocity from the mean of the velocities at 0.2 and 0.8 depth is 0.980 using the WSC meter and 1.038 using the USGS meter. The average coefficient for obtaining the mean velocity from that at 0.5 is 0.969 using the WSC meter and 0.916 using the Vane meter. For 0.6 depth, the average coefficient for obtaining the mean velocity is 0.960 using the WSC meter and 0.937 using the Vane meter.

It should be pointed out that the vertical velocity curves at Drayton were through the cross section (i.e. bank and midstream) in contrast to Emerson where the velocity profiles were all selected close to the bank.

The values of the coefficient necessary to convert the velocity obtained by the two- or one-point method to the mean velocity are presented in Tables 27 and 28.

It is not possible to draw direct conclusions based on the relatively small number of observations performed on the Red River. However, it can be observed that the coefficients necessary to convert the velocity obtained by the two- (0.2 and 0.8 d) and one- (0.5 or 0.6 d) point method to the mean velocity may not be 1.00 and 0.88 or 0.92 in all cases. In fact, at Drayton, the coefficients were 1.00 (WSC1) and 1.05 (USGS) for the two point method, and 0.95 (WSC1) for the 0.5 depth method and 0.97 for the 0.6 depth method (USGS). Moreover, the sampling of several vertical velocity curves to determine the appropriate coefficient appears to be justified and should be considered for inclusion in Canadian hydrometric standards. This procedure is already recommended in USGS standards (see Buchanan and Somers, 1980), although it is not a standard field practice.

In their report Barrows and Horton mentioned that the study of the flow under ice cover was just starting (in 1907), and in order to systematize the data collection and processing, it was desirable to follow certain general methods that they recommended. These methods, still in use 80 years later, have not yet been fully investigated.

In a recent study, Lawson et al. (1986) stated that there are possibly several reasons why field investigations and data for streamflow under ice cover are lacking:

- "general logistical problems inherent to working on an ice cover during low temperatures";
- "lack of suitable methods and sampling equipment for use in winter";
- "perhaps an underlying assumption that sediment and water discharge are severely reduced during the ice covered period and therefore of less interest than during the open water period."

However, with the help of new technology, computers, and data acquisition systems, the analysis of the velocity measurements under ice cover is now feasible, and should be considered as a research area to improve the quality of streamflow records under ice conditions. To carry out this investigation, a hanger bar with 10 current meters spaced at 0.10-depth intervals should be used (Savini and Bodhaine, 1971).

Table 27. Coefficients Required to Convert Point Velocity to Mean Velocity, Vertical Velocity Profiles, Red River at Drayton

Relative Depths	Vertical 30		Vertical 49		Vertical 67		Mean Ratio	
	WSC1	USGS	WSC1	USGS	WSC1	USGS	WSC1	USGS
0.10 d	1.102	1.008	1.051	1.056	1.038	1.003	1.063	1.022
0.20 d	0.934	0.949	0.953	0.971	0.944	0.982	0.943	0.967
0.30 d	0.913	0.908	0.959	0.904	0.919	0.923	0.930	0.912
0.40 d	0.934	0.908	0.851	0.904	0.907	0.905	0.897	0.906
0.50 d	0.988	0.928	0.899	0.925	0.950	0.885	0.946	0.913
0.60 d	0.962	1.029	0.959	0.947	0.987	0.942	0.969	0.973
0.70 d	1.089	1.029	1.024	0.992	1.023	0.982	1.045	1.001
0.80 d	0.971	1.070	1.137	1.174	1.061	1.176	1.057	1.140
0.90 d	1.169	1.258	1.301	1.230	1.249	1.358	1.239	1.282
0.2 & 0.8 d	0.953	1.010	1.045	1.073	1.002	1.079	1.000	1.054
Mean Velocity	0.288	0.293	0.317	0.314	0.282	0.280		

Note: Coefficient required to convert point velocity to mean velocity and computed as: $\frac{Vm}{Vp}$

Table 28. Coefficients Required to Convert Point Velocity to Mean Velocity, Vertical Velocity Profiles, Red River at Emerson

Relative Depths	Vertical 6		Vertical 9		Vertical 12		Mean Ratio	
	WSC1	USGS	WSC1	USGS	WSC1	USGS	WSC1	USGS
0.10 d	1.105	1.267	1.002	1.019	0.984	0.984	1.031	1.090
0.20 d	1.010	1.043	0.946	0.972	0.820	1.007	0.925	1.007
0.30 d	0.964	1.011	0.909	0.929	0.970	0.899	0.948	0.946
0.40 d	1.001	0.953	0.909	0.887	0.908	0.889	0.939	0.910
0.50 d	1.001	0.940	0.925	0.910	0.981	0.899	0.969	0.916
0.60 d	0.941	0.940	0.909	0.910	1.029	0.962	0.960	0.937
0.70 d	0.985	0.940	1.061	1.019	1.033	0.984	1.026	0.981
0.80 d	0.912	0.940	1.084	1.112	1.110	1.156	1.035	1.070
0.90 d	1.116	1.043	1.433	1.415	1.296	1.386	1.282	1.281
0.2 & 0.8 d	0.961	0.991	1.015	1.042	0.965	1.082	0.980	1.038
Mean Velocity	0.234	0.200	0.254	0.255	0.270	0.258		

Note: Coefficient required to convert point velocity to mean velocity and computed as: $\frac{Vm}{Vp}$

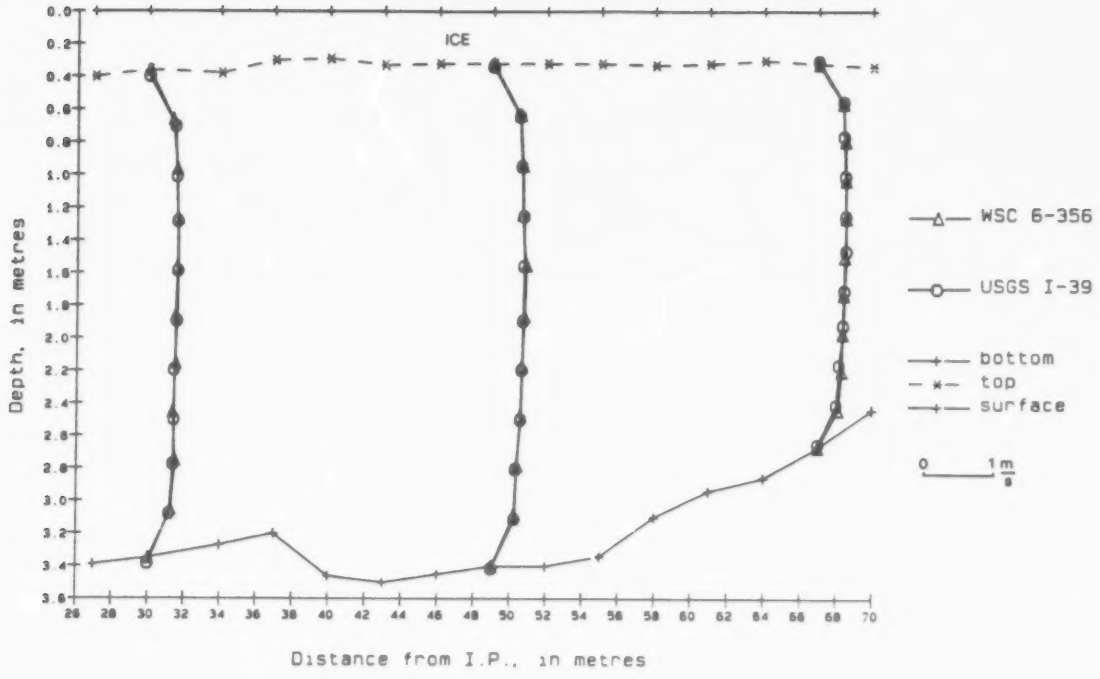


Figure 37. Vertical velocity curves on the Red River at Drayton.

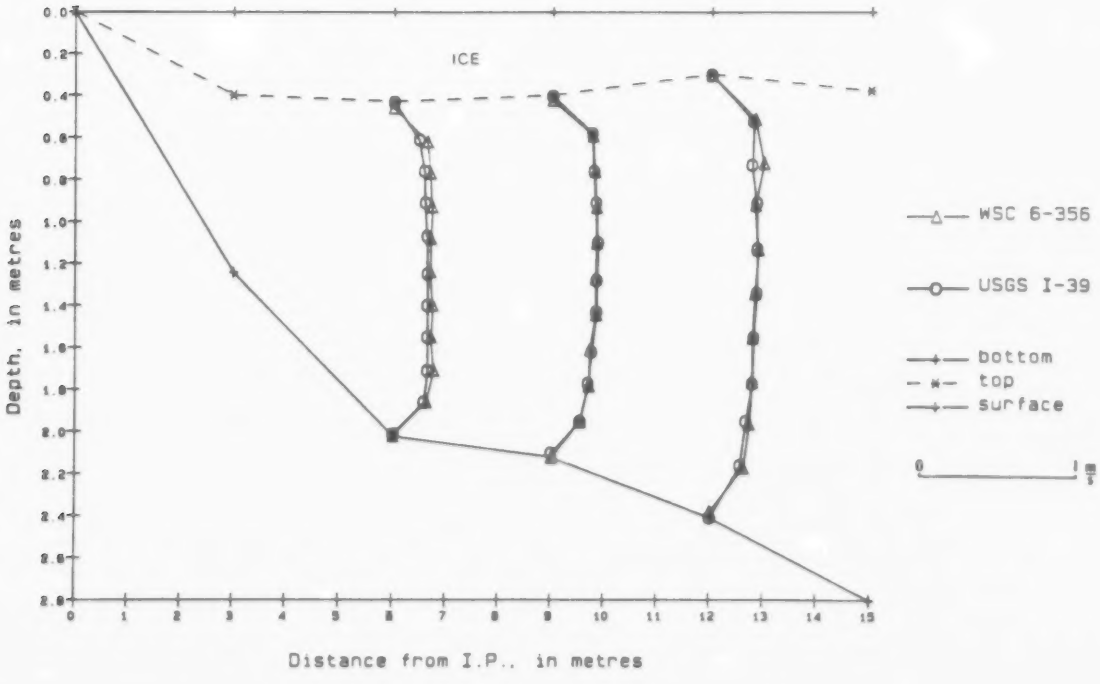


Figure 38. Vertical velocity curves on the Red River at Emerson.

4.6 Effect of Limited Exposure

The velocity at any point in a stream is continuously and randomly fluctuating with time. These fluctuations are known as pulsations or oscillations.

Pulsations are present in all open channels in some form and are caused by hydraulic conditions in the river, such as obstructions, bends or rapids, and the general regime of the river.

Because of turbulence the velocity fluctuates continuously over the wet cross section. The mean velocity at any point determined from a measurement during a certain time interval is an approximation of the true mean velocity at any particular point. Therefore, an error is introduced. This error in discharge is related to the time period of observation of velocity at a point.

Pulsations were distinctly observed on the Red River at Emerson and data collected. Three verticals in the cross section were used, and simultaneous measurements were taken at 0.8 and at 0.2 of the total depth. Velocity observations were recorded the first 50 s of each minute for a 10-min period. The data collected with WSC winter meters 6-356 and 6-288 were presented, respectively, in Tables 9 and 10, and the data collected with USGS Vane ice meter I-39, in Table 11 in Section 3.1.2.

The extent of the pulsations is shown in Figure 39. The relationship plotted is the velocity versus time. The duration of the pulsation wave, at this point in the vertical, is between 6 and 7 min. The variation in mean velocity is greater at 0.8 depth than at 0.2 depth. To quantify this variation in mean velocity, the standard deviations were calculated as in Table 29.

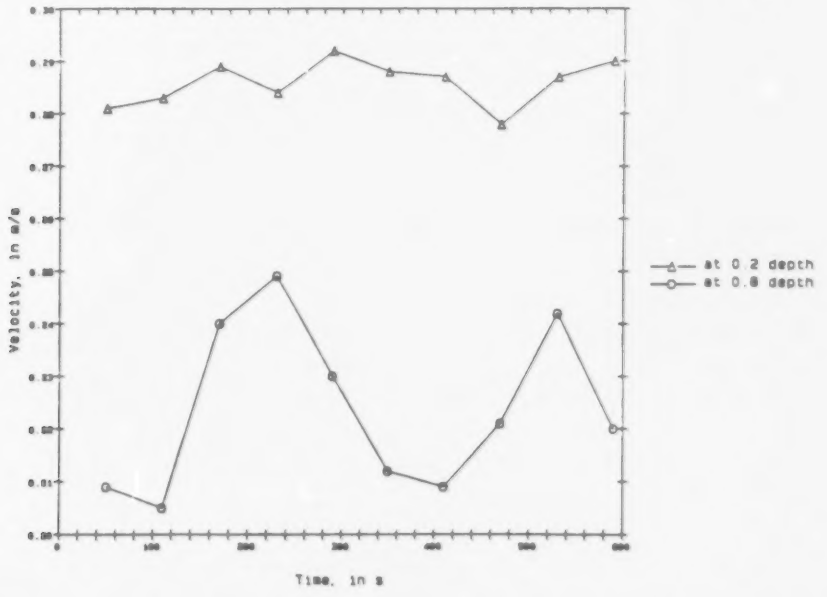


Figure 39. Pulsations at vertical 12 m on the Red River at Emerson on January 23, 1986, with WSC winter meter 6-356.

The uncertainty due to the limited exposure time was computed and is expressed as the percentage standard deviation (95% level). The percentage standard deviation at the 95% level is defined as the coefficient of variation and computed as two times the standard deviation divided by the mean, and multiplied by 100. These results are presented in Table 29. The uncertainty is defined as the interval within which the true value of a measured quantity can be expected to lie with a stated probability. It can be observed that the uncertainty is higher at 0.8 depth than at 0.2 depth, in other words, the standard deviations appeared to follow the values of the velocities and increased from the surface to the bed as the velocities decreased.

The results in Table 29 also indicates that the USGS vane meter on rod suspension gives higher velocities than the WSC winter meter on rod suspension when there are velocity pulsations. This confirms the observations of the limited flume experiments that the USGS vane meter gives higher velocities when subjected to turbulent flow.

The pulsation phenomenon has been the subject of several investigations, including those of Dement'ev (1962), Carter and Anderson (1963), Herschy (1975), and ISO 748 (1979). These studies indicated the following:

- the error due to pulsations varied with depth and with the position of the vertical in the cross section;
- the uncertainty due to pulsations varied with the velocity, i.e., in general the uncertainty increased from the surface to the bed as the velocities decreased;
- the uncertainty due to pulsations decreased with an increase in the time of exposure;
- the pulsations and their effect varied from river to river.

Also, Dement'ev (1962) concluded that the magnitude of pulsation increases with the roughness of the bed. Earlier Russian work in the period 1870-1900 had concluded that pulsation increases with an increase in roughness, especially with an ice cover.

However, generally these investigations into pulsation effects were conducted under open water conditions.

A comparison can be made with results obtained by the International Organization of Standardization. Using the results for vertical 12 m (Table 29), derived with WSC winter meter 6-356, the percentage standard deviation (95% level) for a 50-s observation at 0.2 depth is 3% and 14% at 0.8 depth. In comparison, ISO (1979) suggests uncertainty values of 8% at 0.2d and 12% at 0.8d. The velocity pulsations at 0.8 and at 0.2 of the depth for all the simultaneous measurements are presented in Figures 40 and 41.

In summary, an exposure time of 40 to 60 s may not be sufficient to produce a measurement of acceptable accuracy. Therefore further investigation into the effect of pulsations on the accuracy of river flow measurement would be beneficial to increase our knowledge of the phenomenon. Special instrumentation would be necessary to conduct such investigations, for example, an ultrasonic velocity meter; or a current meter with an optical head that would give the instantaneous velocity. Such instrumentation has been developed by the Water Survey of Canada and by the U.S. Geological Survey but has not been used in general in field operations (Fig. 42).

The methodology for conducting such a study has been developed by the International Organization for Standardization (1985). Also, to carry out this investigation, a hanger bar with 10 current meters spaced at 0.10-depth intervals should be used (Savini and Bodhaine, 1971).

Table 29. Percentage Standard Deviation (95% level) of velocity pulsations for 50-s Exposure Time

			Mean Velocity in Vertical					
			6 m		9 m		12 m	
Crew	Suspension	Meter	0.2d	0.8d	0.2d	0.8d	0.2d	0.8d
Mean*								
WS1	Rod	6-356	0.230	0.233	0.271	0.222	0.286	0.224
WS2	Cable	6-288	0.249	0.229	0.285	0.224	0.284	0.233
USGS	Rod	I-39	0.238	0.245	0.273	0.239	0.294	0.255
Standard Deviation								
WSC1	Rod	6-356	0.005	0.010	0.005	0.011	0.004	0.016
WSC2	Cable	6-288	0.004	0.005	0.006	0.015	0.007	0.007
USGS	Rod	I-39	0.004	0.008	0.006	0.012	0.007	0.015
Percentage Standard Deviation (95% level)								
WSC1	Rod	6-356	4.35	8.58	3.69	9.91	2.80	14.3
WSC2	Cable	6-288	3.21	4.37	4.21	13.4	4.93	6.01
USGS	Rod	I-39	3.36	6.53	4.40	10.0	4.76	11.8

*Mean velocities were computed using February 1986 composite ratings developed at CCIW.

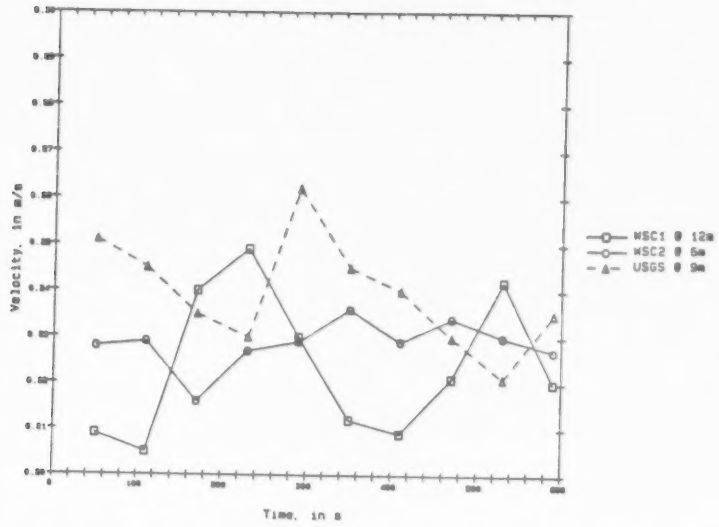


Figure 40a. Velocity pulsation at 0.8 depth, 1st measurement.

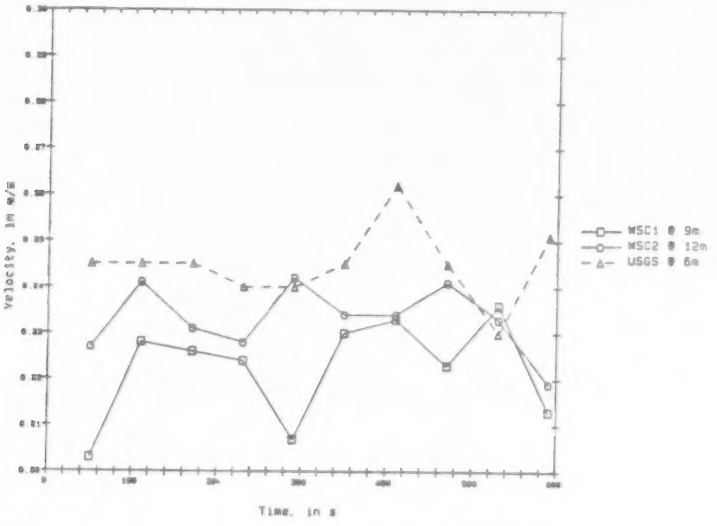


Figure 40b. Velocity pulsation at 0.8 depth, 2nd measurement.

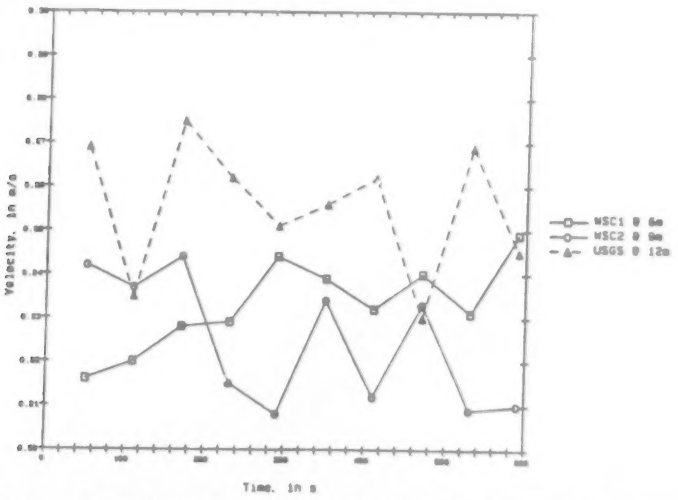


Figure 40c. Velocity pulsation at 0.8 depth, 3rd measurement.

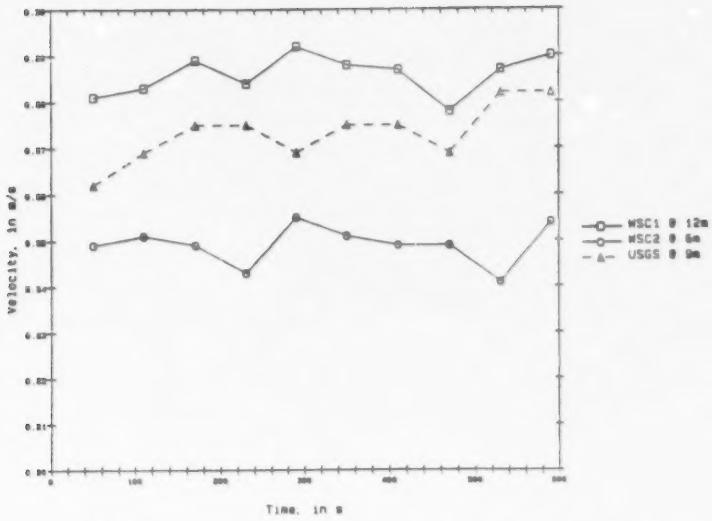


Figure 41a. Velocity pulsation at 0.2 depth, 1st measurement.

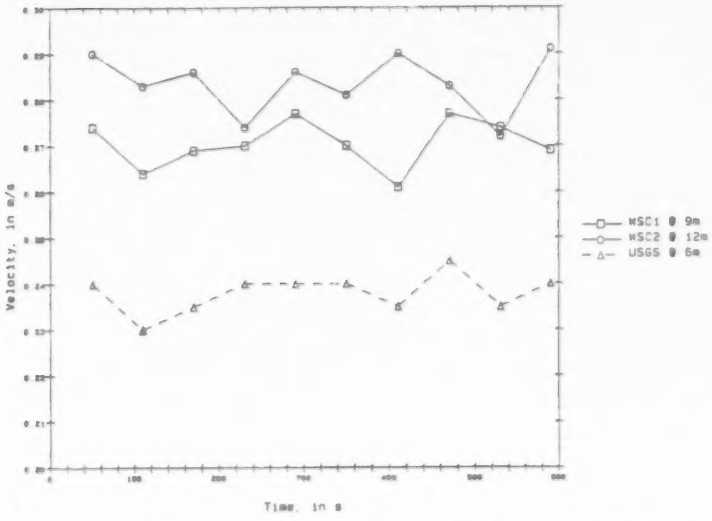


Figure 41b. Velocity pulsation at 0.2 depth, 2nd measurement.

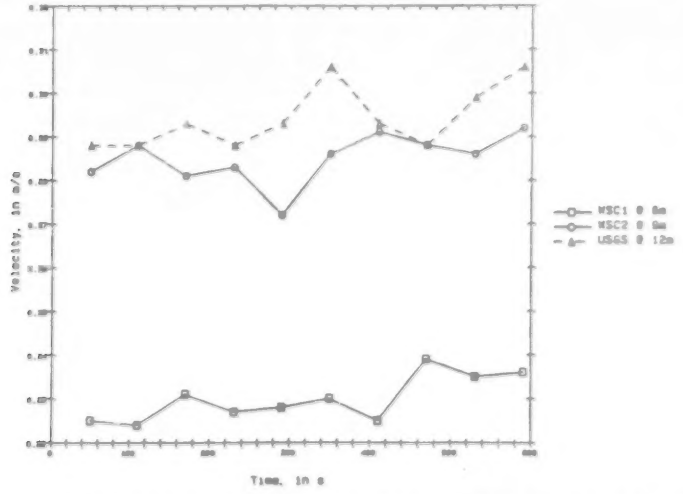


Figure 41c. Velocity pulsation at 0.2 depth, 3rd measurement.

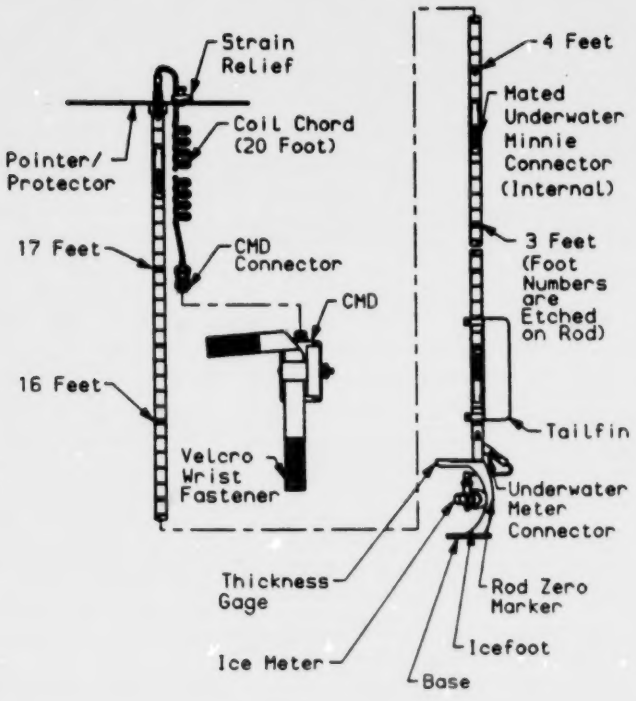


Figure 42a. Ice metering system (after Futrell II, 1986).

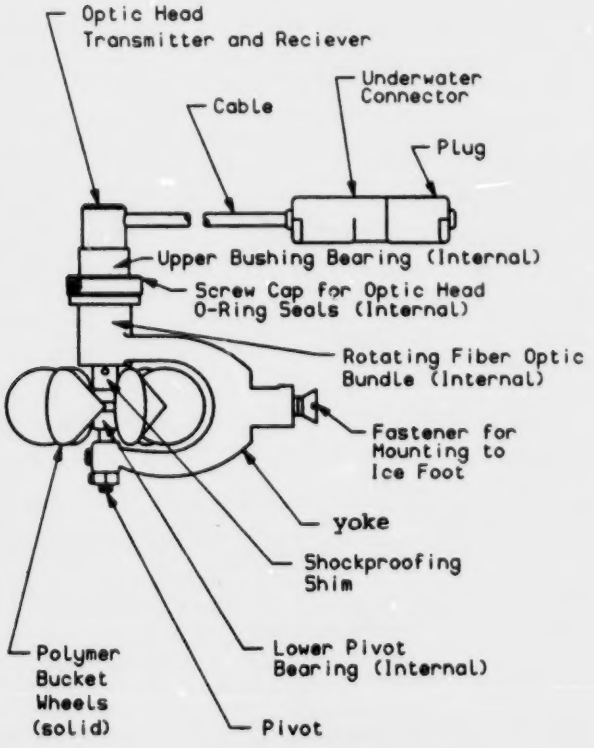


Figure 42b. F-Combination current meter (after Futrell II, 1986).

5. CONCLUSIONS

Computed streamflows on the Red River at Drayton, N.D., have been found to be generally higher, under winter conditions, than on the Red River at Emerson, Man. The hydrometric gauging station at Drayton is located 85 km upstream from Emerson. There are several gauged tributaries between the two stations. The difference between Drayton and Emerson monthly streamflows under ice conditions ranges from +5% to 10%.

Historically, the U.S. Geological Survey has measured higher streamflows than Water Survey of Canada on the Red River at the Emerson International Gauging Station. The difference between USGS and WSC winter streamflow measurements generally ranges between +10% and +20%. This difference is inversely proportional to the velocity, i.e., when the velocity decreases, the difference increases. Usually the equipment used by the USGS is a Vane ice current meter on rod suspension, i.e. winter steel rod. The equipment used by WSC is a WSC winter current meter (Price AA with modified yoke) on cable suspension, i.e., Winnipeg winter weight assembly with "A" reel and tripod.

Several factors assumed to be the cause of these measurement differences were investigated further: streamflow measurement procedures (USGS versus WSC), suspension equipment (rod versus cable), current meter rating procedures (USGS versus WSC Calibration Services) and current meter design (Vane versus cup). Field and laboratory experiments were carried out to determine the effect of these factors.

5.1 Differences in Streamflow Measurement Procedures

There are no significant differences between the USGS and WSC procedures used to measure streamflow under winter conditions.

The number of significant figures used for time and depth measurements is less for the USGS when compared with WSC. Time observations are taken to the nearest second by the USGS and to the nearest 0.2 s by WSC. Depth observations are taken to the nearest 0.03 m (0.10 ft) by the USGS and to the nearest 0.01 m by WSC.

The USGS uses the 0.6 method with a 0.92 coefficient if effective depths are less than 0.75 m, and the WSC uses the 0.5 method with a coefficient of 0.88. The coefficient (0.88) for the middepth method (0.5 depth) was derived from the investigation carried out by the USGS in 1907 by Barrows and Horton.

Usually the depths measured by the USGS are approximately 1% to 1.5% greater than depths measured by WSC. This occurs whether or not WSC is using a rod suspension (winter aluminum rods) or cable suspension (NACA, "A" reel and tripod). The differences may be attributed to the fact that USGS technicians must add to the total depth the difference between the middle of the USGS Vane rotor and the bottom of the yoke, i.e. 0.046 m (0.15 ft). However, USGS technicians in practice add 0.061 m (0.20 ft) for ease of computation, which is 0.015 m too high. Moreover, the difference between the middle of the WSC winter rotor and the bottom of the yoke is 0.045 m, but in practice the value added by WSC technicians is unclear. Therefore the differences in depths may possibly be attributed to this factor. The distance between the middle of the USGS and WSC rotor and the bottom of the yoke is not specified in the hydrometric standards of either country.

As well, the distance between the middle of the WSC winter rotor and the bottom of the winter weight is not always equal to 0.24 m as mentioned in the WSC Hydrometric Field Manual. In fact, the distance for the winter weight used on the Red River at Emerson was 0.30 m. Because each winter weight is custom built and the distance may not be the same for all winter weights, the hydrometric technician should always verify this distance prior to a discharge measurement.

Finally, the use of the winter rod base or foot should be promoted as it protects the current meter. However, its influence on the performance of the winter current meter should be determined.

5.2 Differences between Cable and Rod Suspension

Calibration tests in Canada and the United States determined that the effect of cable suspension on current meter rating is significant. The calibration procedure in Canada is to rate the WSC winter meter on rod suspension only. However, it was shown that if a meter was rated on rod suspension but used in the field on cable suspension, with the NACA weight assembly, significant differences would occur.

It was determined that the WSC winter meter rotates approximately 4% to 17% slower, depending on the velocity, when mounted with the Winnipeg winter weight assembly than when mounted on a rod. For the discharge measurements analyzed, the mean velocity using a current meter on cable suspension is approximately 15% lower than that measured using a current meter on rod suspension. In other words, if a current meter is used on cable suspension but rated on rod suspension, the mean velocities will be largely underestimated.

If the rating equations developed for the current meter on cable suspension are used to compute the discharge measurements, the flow is found to be higher, by approximately 7% (for a mean velocity of 0.3 m/s), than the discharge computed using the current meter equation rated on rod suspension but used on cable suspension.

It was shown that the correction coefficients, which are the velocity ratios for meter and weight assembly rating divided by the meter and rod rating, vary with the velocity (or number of revolution(s) per second) and are very high at low velocities.

There is evidence to conclude that the calibration of a current meter (WSC winter meter or USGS plastic rotor meter) on cable suspension ("A" reel and tripod, or handline) with winter weight assemblies, such as NACA, Pancake and Slush-n-all, may diverge from the rigid rod calibration. The same observation may be valid for the weights used on cable suspension during the open water period, i.e. Columbus weights, with a Price AA current meter. In 1984, a USGS investigation recommended that the Vane ice meter be used only on rod suspension because of the large variable correction coefficients.

A composite rating (two or more equations) is necessary when a meter is rated on cable suspension. The repeatability of the calibration tests of a WSC winter current meter on cable suspension is not as good as for the same meter on rod suspension. The accuracy of the cable suspension ratings decreases drastically at low velocities.

Whether or not a single correction curve may be established to convert a rigid rod rating to a cable rating, for a particular weight assembly type, or that individual weight assemblies must be rated, is unknown. Therefore, more research into the effect of suspension is required, after which an operational policy for the use of current meter on cable suspension could be developed.

5.3 Differences in Current Meter Rating Procedures

The current meter rating procedures differ between the United States and Canada in many ways. In Canada, a current meter is rated for 20 different velocities ranging from 10 to 250 cm/s, whereas in the United States, a current meter is rated for ten different velocities ranging from 3 to 244 cm/s, in both direction (forwards and backwards).

A composite rating (two equations) is usually employed by the U.S. Geological Survey (for the Vane meter) versus a single rating by Water Survey of Canada (for the WSC winter meter). The current meter ratings for open water measurements are also composite in the United States, however, the USGS uses group ratings. In Canada, the current meters for open water measurements have a single rating and are individually rated on rod and on cable suspension (30-lb Columbus weight only).

It was determined that if a meter was rated in Canada and then in the United States, the rating equations for the same meter differed. Also, when the same current meters were rated for a second time in Canada, the calibration results were different. At low velocites, the difference was significant.

The number of tests or runs used to calibrate a current meter, either Vane or cup type, appears to be a significant factor.

For velocities higher than 0.3 m/s, it was found that the difference between ratings derived by the USGS and WSC, for the same WSC winter current meter, is $\pm$1%. However, this difference increases significantly as the velocity decreases below 0.3 m/s.

For velocities higher than 0.3 m/s, the difference between USGS and WSC ratings for the same Vane ice meter is $\pm$2%. As for the WSC winter meter, the difference was found to increase drastically as the velocity decreases below 0.3 m/s.

The calibration repeatability of the WSC winter current meter appears to be better than for the USGS Vane ice current meter.

It was found that a composite rating is necessary for the Vane ice meter. Also, a composite rating for the WSC winter meter (Price AA but with a different yoke) might increase the accuracy of a discharge measurement at low velocities. The standard error of the composite equation is lower than the standard error of the single equation, indicating a better fit through the calibration data when a composite rating is used.

The differences between the rating equations as derived by the USGS and WSC for the WSC winter meter on cable suspension are significantly higher than they were for the rod suspension calibration, i.e. $\pm$4% compared to $\pm$1% at 0.3 m/s. This indicates the difficulty in repeating with high accuracy the rating of a current meter on cable suspension.

The discharge measurement computation using these new current meter rating equations indicated that discharge measurements, under ice cover, taken with WSC winter meters mounted on rod or on cable suspension, but rated accordingly, would agree within 5%. However, discharge measurements, under ice cover, taken with the USGS Vane ice meter mounted on rod suspension would be 0 to 10% higher than the measurements taken with WSC winter meters mounted on rod.

In summary, differences in current meter rating techniques and procedures exist between Canada and the United States, as expected. These differences appear to be significant at low velocities, and further studies in this area would be beneficial for both agencies to determine the best possible rating procedure.

5.4 Differences in Current Meter Design

The rotor of the USGS Vane ice meter is made up four vanes, compared with the rotor of the WSC winter rotor, which comprises six cups. Both meters are vertical axis current meters. The WSC winter meter is simply the rotor of the standard Price AA meter with a modified yoke to facilitate insertion in the holes drilled in the ice cover.

In general, the USGS Vane ice meter gives higher velocities (by 5%) than the WSC winter meter. The velocity difference between the two current meters is higher at low velocities than at high velocities.

The weights of the rotors in air and in water were determined. The dry weight of the Vane rotor is 13% higher than the Price rotor. However, the submerged weight of the Vane rotor is 18% lower than the Price rotor. Because both rotors are not of identical design (Vane vs cup), no firm conclusions may be drawn.

The meters were tested in a 1-metre flume, and it was determined that the WSC winter meter was more precise than the USGS meter, based on two flume measurements. However, additional testing of the current meters in a larger flume (2 m) is necessary to corroborate these results.

An investigation into the design differences of these two meters is needed to determine the specific reasons for the higher velocities as given by the Vane ice meter. Information on the response of the current meter to turbulence may be gained by additional testing of the current meters in flowing water (flumes).

5.5 Other Differences

The effect on the mean velocity of using a limited number of points in the vertical was investigated. The analysis of the vertical velocity profiles, although limited, at Drayton and at Emerson indicated that the use of a coefficient of 1.00 in the case of the two-point method (0.2 and 0.8 depth) and of 0.88 or 0.92 in the case of the one-point method (0.5 or 0.6 depth) may not be the best procedure to use. These standard coefficients were derived from 25 streams in the northeastern United States in 1907 by Barrows and Horton. They recommended that vertical velocity curves be taken for each stream to determine the appropriate coefficient values. In fact, other investigations have indicated that vertical velocity curves should be sampled and that coefficients be derived from these. Although this procedure is described in U.S. Geological Survey standards, in practice, it is generally

not used. The sampling of vertical velocity curves is not mentioned in Canadian standards.

Although the sample size taken on the Red River was small, it indicates the need for more research of the effect of the number of observations taken in the vertical on the accuracy on discharge measurement under winter conditions.

Fluctuations in velocity, i.e. pulsations or oscillations, were observed on the Red River at Emerson, and 10-min velocity observations were taken. The percentage standard deviation (coefficient of variation) at the 95% level was found to range from 3% to 14%, depending on the location in the vertical and in the cross section. The period of the velocity pulsation was 6 or 7 min.

The percentage standard deviation (95% level) is higher at 0.8 depth than at 0.2 depth. These results indicate that a time observation of 50 s for velocity measurement, under winter conditions, may not be sufficient to warrant a measurement of acceptable accuracy.

Further investigation into the effect of pulsations on the accuracy of a discharge measurement, under winter conditions, is necessary to define an acceptable and realistic time for velocity observation, or at least to determine the uncertainty induced when a 50-s observation is taken. New instrumentation, such as an ultrasonic velocity meter, an optical current meter with plastic rotor, and data acquisition equipment, would be essential in conducting such investigations.

5.6 Alternative Procedures for International Gauging Stations

Differences between current meters used by the U.S. Geological Survey and Water Survey of Canada were demonstrated. These differences are generally significant.

It was shown that the WSC winter current meter (Price AA with modified yoke) might be a more appropriate current meter for the measurement of discharge under winter conditions. However, further investigations are necessary to corroborate the Red River findings.

An alternative to the current procedure for the measurement of streamflow under winter conditions by the U.S. Geological Survey and by Water Survey of Canada at an International Gauging Station would be that both agencies use the same type of metering equipment. This equipment on a short-term basis should consist of a WSC winter current meter, with ice foot, and winter rods (aluminum type). On a long-term basis, the metallic rotor on the WSC winter meter might be replaced by a polymer rotor. The use of current meters on cable suspension might also be considered, when their effect is fully understood. The use of the Vane ice meter might also be reconsidered if it proves to be superior to the Price meter, following additional investigations.

Until more research has been completed, the U.S. Geological Survey and Water Survey of Canada should use the same and the most appropriate metering equipment for discharge measurement under ice conditions at International Gauging Stations. Consideration should also be given to measure streamflow under winter conditions with the same type of equipment, at gauging stations located upstream and downstream from International Stations.

6. RECOMMENDATIONS

Recommendation 1

To minimize the differences between USGS and WSC winter streamflow measurements at the International Gauging Station on the Red River at Emerson, and until further research has been completed,

> It is recommended that the WSC winter meter be used on rod suspension, and that composite rating be developed for this type of current meter. However, if winter rods cannot be used due to depths, the WSC winter meter may be used on cable suspension, if it has been calibrated on cable and weight suspension prior to the measurement. The difference of 0.045 m should be added by the technicians to the total depth if the winter rods are used. If a winter weight assembly is used, then the distance from the bottom of the weight to mid-rotor should be added to the total effective depth. A minimum of three vertical velocity curves should be taken to establish the appropriate correction coefficients, relating point and mean velocity. A minimum of 60-s exposure should be taken at each point in the vertical.

The following recommendations all have national and international implications and therefore should be carried out at a national level, by the Water Resources Branch, Ottawa, in close cooperation with the U.S. Geological Survey, Reston.

Recommendation 2

Differences in depth observations occur between the U.S. Geological Survey and Water Survey of Canada. Therefore,

> It is recommended that the difference between the bottom of the yoke and the middle of the metallic rotor of the WSC winter meter, i.e. 0.045 m, be mentioned in Water Survey of Canada National Standards and applied in practice.
>
> It is <u>suggested</u> that the difference between the bottom of the yoke and the middle of the Vane of the USGS Vane ice meter, i.e. 0.046 m, be mentioned in U.S. Geological Survey National Standards and applied in practice.
>
> It is recommended that the influence of the winter rod base or foot on the performance of the winter current meter be determined. If the influence is considered to be negligible, the use of the winter rod base or foot should be standardized.

The difference between the bottom of the Winnipeg winter weight assembly and the middle of the metallic rotor of the WSC winter meter is not constant for all winter weights, and may range from 0.24 to 0.30 m. Therefore,

> It is recommended that this distance be measured by the hydrometric technician prior to the streamflow measurement. Also, this procedure should be included in Water Survey of Canada National Standards.

Recommendation 3

The effect of cable suspension on the WSC winter current meter calibration, and also on other current meters, is significant. Therefore,

It is recommended that a study into the effect of suspension on current meter calibration be undertaken including the effects of the NACA, Pancake, Slush-n-all, and Columbus type sounding weight assemblies. "A" reel and tripod combination, and hand lines should be considered as the suspension equipment to be investigated.

Recommendation 4

Differences between U.S. Geological Survey and Water Survey of Canada current meter calibration procedures were not found to be significant at high velocities. However, at low velocities, i.e. less than 0.3 m/s, the differences became significant. Also, the repeatability of cable suspension ratings appeared to be significantly lower than for rod ratings. Therefore,

It is recommended that an investigation be carried out to determine the most appppropriate current meter calibration procedure for the rating of current meters at low velocities, including the analysis of composite and single ratings.

Recommendation 5

Velocities measured with the USGS Vane ice current meter are different from velocities measured with the WSC winter meter. Therefore,

It is recommended that the design of the Vane and cup type current meter be analyzed, and that the most appropriate current meter for the streamflow measurement under winter ice conditions be recommended for use. These winter current meters should also be compared with polymer current meters of different sizes, materials, and shapes as recently developed by the USGS and WSC with standard (cat's whisker) and optic heads. Comparison with propeller-type current meters, electromagnetic meters (one and two axis) should also be made. These current meters should be rated in still and flowing water (flume).

Recommendation 6

The coefficient for obtaining the mean velocity from the mean of the 0.2 and 0.8 depth is not 1.00 for all streams and conditions. Also, the coefficient for obtaining the mean velocity from that at 0.5 or 0.6 depth is not 0.88 or 0.92 for all streams and conditions. These are <u>average</u> coefficients. Therefore,

It is recommended that an investigation be carried out to determine the variability in the coefficients required for obtaining the mean velocity from the two- and the one-point methods.

It is recommended that vertical velocity curves be sampled (a minimum of three) to establish the appropriate coefficient, for each stream, when using the two- and one-point method of velocity observation. This procedure should be included in the Water Survey of Canada National Standards.

Recommendation 7

Fluctuations in velocity were observed on the Red River at Emerson and are generally present in all streams. The effect on the accuracy of streamflow measurements is poorly understood. The standard time of exposure of 50 s may not be sufficient for velocity observation under winter conditions. Therefore,

> It is recommended that an investigation into the uncertainty in a discharge measurement due to the limited time of exposure be carried out, and that a recommendation be made on an acceptable and realistic time of exposure.

Recommendation 8

Until the investigations recommended (recommendations 2 to 7 above) have been carried out, and their results fully assessed and compared with the results of the limited analysis presented in this report,

> It is recommended that the methods and metering equipment used by the U.S. Geological Survey and by Water Survey of Canada for discharge measurements under ice conditions at International Gauging Stations be the same or that allowances for differences be made. The limited analysis indicates that the preferred metering equipment should consist of a WSC winter current meter with ice foot on winter rod suspension.

This recommendation is to provide the best possible streamflow estimate, under winter conditions, at an International Gauging Station.

The areas of research outlined in this report are compatible with those described by this author in a recent state-of-the-art literature review of the uncertainties in the determination of river discharge (Pelletier, 1987).

These investigations into the measurement of streamflow under winter conditions should be carried out jointly by the U.S. Geological Survey and by Water Survey of Canada. In conducting such investigations, sufficient tests should be taken to ensure that the results are statistically significant. Once they have been completed, a recommendation should be made on the feasibility of correcting the historical data base, if required.

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APPENDIX A

STATION DESCRIPTION AND PROFILE

Manitoba - N.W. Ontario Region

Hydrometric Station Profile

RED RIVER AT EMERSON 05OC001

STATION BACKGROUND

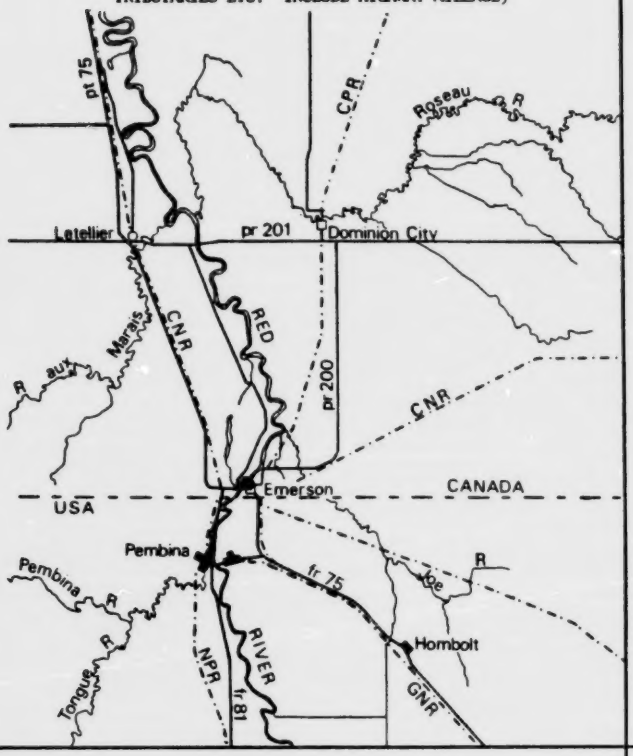
The station was established in 1912 by the Manitoba Hydrographic Survey, and has been classified as an international gauging station since 1930. The stage discharge relationship is well defined, and tends to loop in some years. Record quality is considered to be good. Discharge records have been maintained on a continuous basis since 1912. Sediment measurements are available for the years 1956 and 1961, and continously since 1978.

CURRENT STATUS

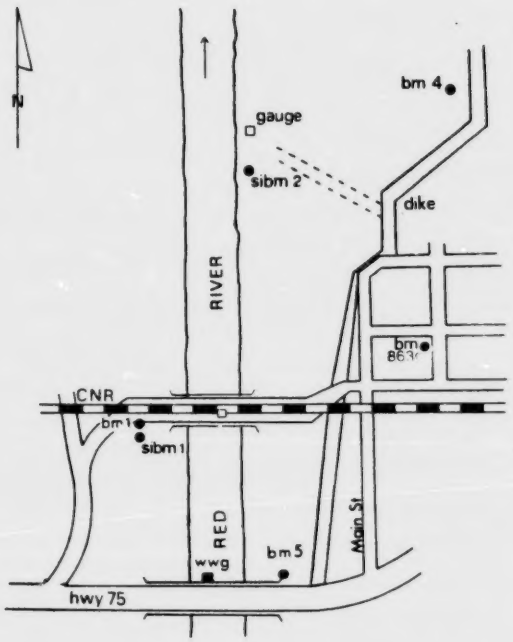
The cost/share classification is F3, International Waters. Manitoba Water Resources Branch (MWRB) uses the data for flood forecasting and operation. The city of Winnipeg, Federal Water Quality Branch, Environmental Protection Agency (EPA-US) and MWRB receive the data on a monthly basis. Data for this station are requested more frequently than any other in the Manitoba region.

INTERNATIONAL GAUGING STATION

SKETCH SHOWING STATION LOCATION
(SHOW NEARBY TOWNS, RAILROADS, HIGHWAYS TRIBUTARIES ETC. INCLUDE HIGHWAY MILEAGE)



SKETCH SHOWING LOCATION OF BENCH MARKS, GAUGING EQUIPMENT AND OBSERVERS RESIDENCE



B.M.#5 - on Hwy 75 traffic bridge. Brass plug on W. side on top wingwall of E. 3'7"(1.1 m) from N end Elevation 790.523 240.951 m (1979 Adj)

DEPARTMENT OF THE ENVIRONMENT
INLAND WATERS DIRECTORATE, WATER SURVEY OF CANADA

DESCRIPTION OF STATION

Station No. 050C001 Drainage Area 104,000 sq km (40,200 sq mi)
Station Name: RED RIVER AT EMERSON
Prov: Manitoba
Name of Observer: Casey's Service Telephone 373 2277
Mailing Address - Emerson, Manitoba

Location: Lat: 49° 00' 30" Long: 97° 12' 40"
in Lot 3, Block A, Town of Emerson.
Established 1912. Recorder well 460 m (1500 ft) d/s from CNR bridge and 1.2 km (3/4 mile) d/s from International Boundary.

Description of gauging equipment, location and Initial Point of Sounding: Steven's A-35 and telemark, staff gauge in well, Contact gauge in shelter.WWG on downstream side of HWY #75 traffic bridge. Measurements from downstream side of Hwy 75 bridge,I.P. -edge of concrete wingwall on right bank d/s side at 10-foot intervals.

Description of Control and Measuring Sections:
Streambed: clay. Subject to overflow at high stages. Possible backwater during periods of high flows on the Roseau River. Overflow section on railroad track at Noyes, Minn., when main channel has flow in excess of approximately 40,000 cfs. 1130 CMS

ELEVATION OF GAUGE DATUM AND DESCRIPTION OF BENCH MARKS

Elevation of Gauge Datum: Zero all gauges 213.360m (700.00 ft)

BENCH MARK DESCRIPTION AND ELEVATION

BM 863C - Fundamental BM pier in grounds of courthouse at Emerson.
Elevation - 240.243 m (788.20 ft)

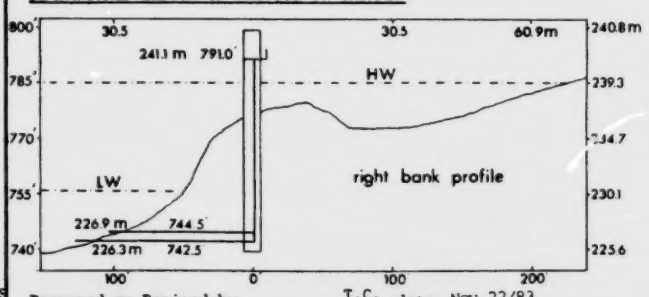
SIBM 2 - Brass cap 5.8 m (19 ft) south of A-frame pedestal on east side of river.
Elevation - 236.820 m (776.97 ft)

BM 4 - Brass cap 66 m (217 ft) north of first hydro pole SE of gauge house and 24 m (78 ft) west of centreline of dyke.
Elevation - 238.838 m (783.59 ft)

SIBM 1 - Brass cap 9 m (30 ft) south of west end of CNR bridge set at ground level.
Elevation - 237.461 m (779.07 ft)

BM 3 - Top of re-bar in concrete block marked red underneath west end of CNR bridge.
Elevation - 238.332 m (781.93 ft)

DIMENSIONED SKETCH OF ORIFICE OR INTAKES



Prepared or Revised by T.C. date Nov 22/83

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION

Station No. 05092000

Description
revised 7-9-86
by W.R. Westensee

Description of Gaging Station --RED RIVER OF THE NORTH AT DRAYTON, N.D.

LOCATION--Lat 48'34'20", long 97'08'50", on line between sections 24 and 25, T.159 N., R.51 W., Pembina County, Hydrologic Unit 09020311, on the downstream end of the east pier of the Interstate Highway Bridge, 1 1/2 mi northeast of Drayton at mile 207.

Gage can be reached by driving 1/2 mi north from Drayton on State Highway 44, then east 1 mi to bridge.

DRAINAGE AREA--34,800 mi^2.

ESTABLISHMENT--Established April 1, 1936, by K.B. Nelson.

GAGE--A Fischer-Porter digital recorder and an A-35 Stevens recorder are operated by a splined float pulley in a steel shelter over the downstream end of the middle pier.

An inside staff gage of standard enamel sections, ranging from 0.00 ft to 40.74 ft, is mounted in the well. The outside gage is a type-A wire-weight gage on the downstream handrail about 20 ft west of the recorder shelter. Datum of the gage is 755.00 ft above msl.

The National Weather Service installed a telemark in the fall of 1977. The telephone number is 454-3424.

Electricity is supplied by PKM Electric Cooperative, Inc., Box 108, Warren, MN 56762. Telephone: 218-745-4711.

Elevations of pertinent features of gaging structure:

Instrument shelf	44.9
House floor	42.0
Bottom of well	-3.0
Maximum gage height instrument will record	43.76

INTAKES--

	Size	Length	Elevation	Device on End
Lower	2"	12"	0.0 ft	Flush with wall
Middle	2"	12"	2.0 ft	Flush with wall
Upper	2"	12"	4.0 ft	Flush with wall

FLUSHING SYSTEM--Well may be flushed by pumping water into or out of the stilling basin through one of the three 4" openings on the east face of the well. These openings are at elevations 3.0, 6.0, and 9.0 ft and are closed with a standard pipe plug on the outside end. The well should be pumped out at least once each year.

CHANNEL AND CONTROL--Low water control is a flat crested dam located one mile below the gage. The dam submerges at about a 15-ft stage. The channel is the control for high stages. Light to heavy growth of trees exists along the channel. Stage-discharge relation is seriously affected at high stages by changing stage and backwater from tributaries. Banks are subject to much overflow at high stages. At a stage of 38 ft, water starts to bypass the gage on highway west of bridge. Flood of April, 1966, at peak stage of 42.15 ft had 3,285 ft of overflow over the highway.

DISCHARGE MEASUREMENTS--Measurements are made from downstream side of bridge at gage. Station markings are painted at 5-ft intervals on upstream and downstream side of bridge with initial point at right abutment. Ice measurements can be made in vicinity of gage. A shelter housing power equipment is located at the gage site.

OBSERVER--Mr. James Weinlaeder, Drayton, N.D. 58225. Works at the Crystal Sugar Plant located 1 mi north of Drayton. Telephone: 454-3326.

HISTORY--The gage was established in April, 1936, at a site 1 1/2 mi upstream at the old highway bridge location. Records fragmentary prior to April, 1949. The gage was moved to the present site November 30, 1954.

FLOODS--Maximum discharge 92,900 cfs, gage height 43.66 ft, occurred April 28, 1979. (Datum at location 1 1/2 mi upstream - which is about 1 ft higher).

POINT OF ZERO FLOW--Crest elevation of dam is 8.00 ft gage datum, from levels by the State Water Commission.

WINTER FLOW--State-discharge relation seriously affected by ice. Heavy ice cover with rather uniform flow.

REGULATION--Flow regulated by storage in lakes and several reservoirs above station.

DIVERSION--Some for municipal and industrial use, most of which is returned to the river.

ACCURACY--Good records can be obtained if frequent measurements are made at times of rapidly changing stage and backwater from tributaries.

COOPERATION--U.S. Department of State-Waterways Treaty.

REFERENCE MARKS--Datum of gage was determined from a standard Minnesota highway bronze tablet on top of SW corner of the east abutment. Elevation is 796.14 ft above msl. Datum of gage is 755.00 ft above msl.

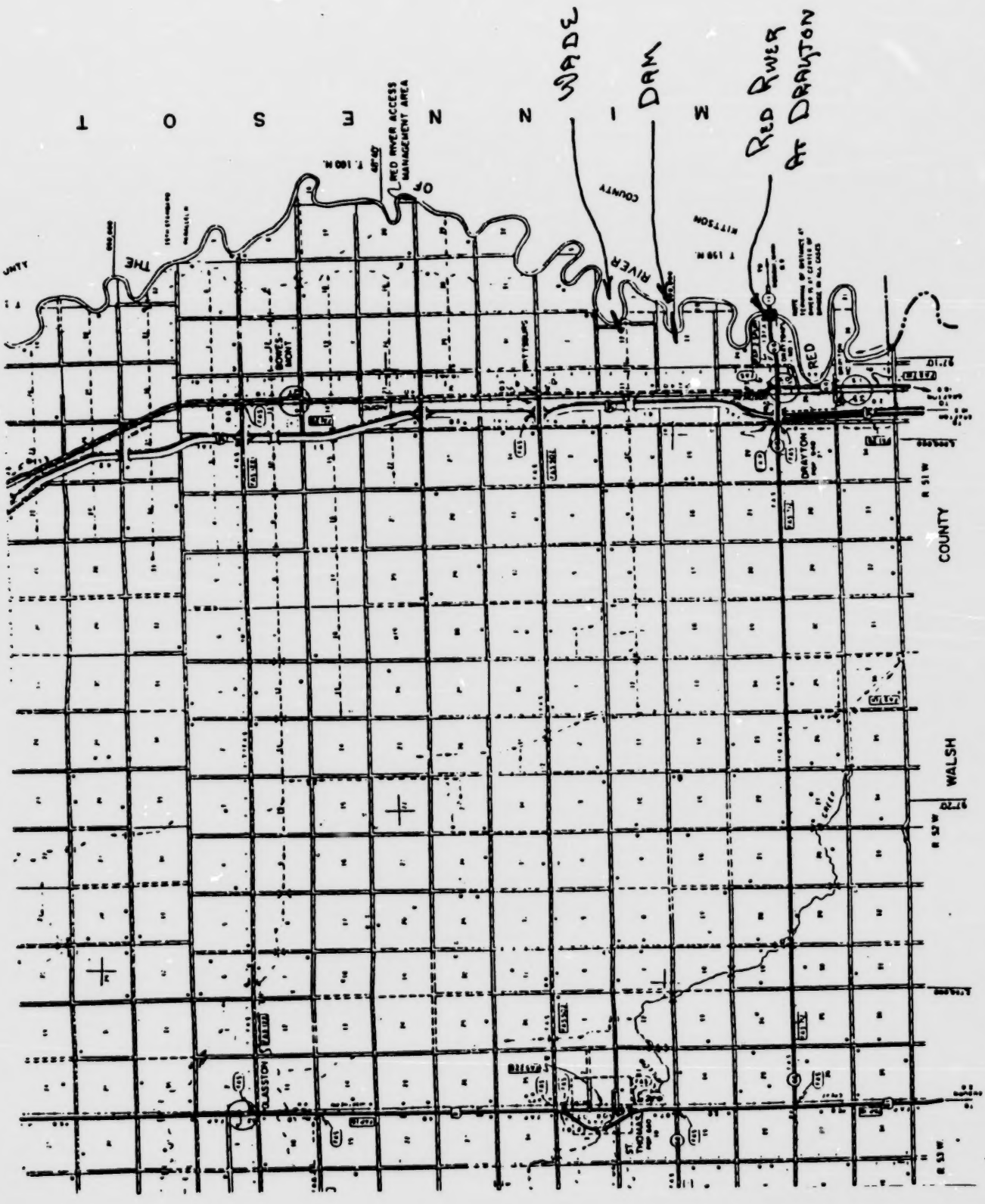
RM#1-is a chiseled square on top of the west wall of concrete house well directly above the inside staff. Elevation 49.216 ft, gage datum. Destroyed.

RM#2-Minnesota highway bronze tablet on SW corner of the east bridge abutment. Elevation 41.14 ft, gage datum and 796.14 ft above msl. (Basis for msl).

RM#3-Minnesota highway bronze tablet on NE corner of the west bridge abutment. Elevation 39.92 ft, gage datum and 794.92 ft above msl.

RM#4-is a chiseled square 49 ft east of right end of handrail of bridge, and 77 ft north of center line of highway, and on southeast corner of concrete porch.

RM#5-is the head of a 3/8" lag screw in the southwest base of box elder tree 215 ft east of right end of handrail, and 42 ft north of center line of highway.


WADE DAM
RED RIVER AT DRAYTON
RED RIVER ACCESS MANAGEMENT AREA
COUNTY
WALSH
COUNTY
RIVER
RED
DRAYTON
BOWES MONT
CLASSTON
ST THOMAS
R 51W
R 52W
R 53W

APPENDIX B

FIELD MEASUREMENTS COLLECTED ON THE RED RIVER

Measurements with WSC Winter Meter 6-356

TABLE 1 RED RIVER AT DRAYTON,ND JANUARY 21, 1986

1ST MEASUREMENT - WSC1 WITH WSC WINTER METER 6-356 ON ROD

STATION	WIDTH	DEPTH	COEFF	REV 0.2D	TIM 0.2D	VEL 0.2D	REV 0.8D	TIM 0.8D	VEL 0.8D	MEAN VEL.	AREA	FLOW
0.91	1.8300	0.0000	1.00	0	0.0	0.000	0	0.0	0.000	0.000	0.000	0.0000
4.57	4.1100	0.7800	0.88	10	68.0	0.096	10	68.0	0.096	0.096	3.206	0.3093
9.14	3.8100	2.1300	1.00	15	42.0	0.250	12	40.8	0.208	0.229	8.115	1.8575
12.19	3.0500	2.2800	1.00	20	52.6	0.265	15	40.8	0.257	0.261	6.954	1.8161
15.24	3.0500	2.4400	1.00	16	41.0	0.272	15	43.2	0.243	0.258	7.442	1.9176
18.29	3.0500	2.6000	1.00	20	47.0	0.296	17	41.6	0.284	0.290	7.930	2.2995
21.34	3.0500	2.8500	1.00	20	49.0	0.284	15	41.8	0.251	0.268	8.692	2.3256
24.38	3.0500	2.8800	1.00	20	48.4	0.287	15	40.2	0.261	0.274	8.784	2.4069
27.43	3.0500	2.9600	1.00	20	46.4	0.299	15	39.0	0.268	0.284	9.028	2.5620
30.48	3.0500	2.9900	1.00	20	47.2	0.294	15	42.0	0.250	0.272	9.119	2.4821
33.53	3.0500	2.8800	1.00	20	44.2	0.314	20	48.6	0.286	0.300	8.784	2.6346
36.58	3.0500	2.8800	1.00	20	47.2	0.294	20	50.4	0.276	0.285	8.784	2.5072
39.62	3.0500	3.1500	1.00	20	45.0	0.308	20	47.2	0.294	0.301	9.607	2.8950
42.67	3.0500	3.1700	1.00	20	43.0	0.322	20	48.2	0.289	0.305	9.668	2.9517
45.72	3.0500	3.1000	1.00	20	43.6	0.318	15	39.4	0.266	0.292	9.455	2.7583
48.77	3.0500	3.0800	1.00	20	42.6	0.325	15	39.6	0.264	0.295	9.394	2.7682
51.82	3.0500	3.0600	1.00	20	43.4	0.319	20	45.0	0.308	0.314	9.333	2.9279
54.86	3.0500	3.0000	1.00	20	42.0	0.329	20	51.6	0.270	0.300	9.150	2.7437
57.91	3.0500	2.7500	1.00	20	49.0	0.284	20	50.6	0.275	0.280	8.387	2.3460
60.96	3.0500	2.6000	1.00	20	46.0	0.302	20	45.8	0.303	0.302	7.930	2.3982
64.01	3.0500	2.5000	1.00	20	46.6	0.298	20	51.0	0.273	0.286	7.625	2.1784
67.06	3.0500	2.3300	1.00	20	50.0	0.279	15	41.2	0.255	0.267	7.106	1.8943
70.10	3.0500	2.0600	1.00	20	50.2	0.277	15	43.4	0.242	0.260	6.283	1.6328
73.15	3.0500	1.9300	1.00	20	51.0	0.273	15	42.4	0.248	0.261	5.886	1.5335
76.20	3.8100	1.8300	1.00	15	42.8	0.245	15	48.0	0.220	0.233	6.972	1.6231
80.77	4.5700	1.8500	1.00	10	43.0	0.167	15	46.4	0.227	0.197	8.454	1.6657
85.34	4.5700	0.8000	0.88	10	46.6	0.136	10	46.6	0.136	0.136	3.656	0.4978
89.92	2.2900	0.0000	1.00	0	0.0	0.000	0	0.0	0.000	0.000	0.000	0.0000

DATE:	86-01-21
TIME:	1100-1230
METER NO:	WSC 6-356
SUSPENSION:	ROD
A1:	0.6679
B1:	0.0114
BREAK IN REV/S:	10.0000
A2:	0.6679
B2:	0.0114
DATE RATED:	84-10-01
RATED AT:	CCIW
RATED ON:	ROD
REMARK:	ORIGINAL
NO. OF VERT.:	28.0000
WIDTH (M):	89.0400
MEAN VEL. (M/S)	0.2719
AREA (SQ. M.):	205.7484
DISCHARGE (CMS)	55.9330

TABLE 2 RED RIVER AT DRAYTON,ND JANUARY 21, 1986

2ND MEASUREMENT - WSC1 WITH WSC WINTER METER 6-356 ON ROD

STATION	WIDTH	DEPTH	COEFF	REV 0.2D	TIM 0.2D	VEL 0.2D	REV 0.8D	TIM 0.8D	VEL 0.8D	MEAN VEL.	AREA	FLOW
0.91	1.8300	0.0000	1.00	0	0.0	0.000	0	0.0	0.000	0.000	0.000	0.0000
4.57	4.1100	0.7900	0.88	10	67.8	0.097	10	67.8	0.097	0.097	3.247	0.3140
9.14	3.8100	2.1600	1.00	15	46.0	0.229	12	41.8	0.203	0.216	8.230	1.7790
12.19	3.0500	2.2600	1.00	15	39.6	0.264	20	50.4	0.276	0.270	6.893	1.8640
15.24	3.0500	2.4700	1.00	15	40.8	0.257	15	44.2	0.238	0.248	7.533	1.8646
18.29	3.0500	2.6200	1.00	20	50.0	0.279	15	42.0	0.250	0.264	7.991	2.1116
21.34	3.0500	2.8700	1.00	15	39.0	0.268	15	42.8	0.245	0.257	8.754	2.2486
24.38	3.0500	2.9000	1.00	20	47.6	0.292	15	45.6	0.231	0.262	8.845	2.3136
27.43	3.0500	2.9900	1.00	20	49.2	0.283	20	57.0	0.246	0.264	9.119	2.4105
30.48	3.0500	2.9900	1.00	20	46.4	0.299	15	39.0	0.268	0.284	9.119	2.5880
33.53	3.0500	2.8900	1.00	20	48.0	0.290	15	44.0	0.239	0.264	8.814	2.3305
36.58	3.0500	2.9000	1.00	20	46.0	0.302	15	40.6	0.258	0.280	8.845	2.4764
39.62	3.0500	3.1700	1.00	20	42.2	0.328	20	52.0	0.268	0.298	9.668	2.8823
42.67	3.0500	3.1700	1.00	20	42.0	0.329	20	46.0	0.302	0.316	9.668	3.0516
45.72	3.0500	3.1300	1.00	20	42.4	0.326	16	42.0	0.266	0.296	9.546	2.8271
48.77	3.0500	3.0800	1.00	20	47.0	0.296	20	50.0	0.279	0.287	9.394	2.6969
51.82	3.0500	3.0800	1.00	20	43.8	0.316	20	46.2	0.301	0.308	9.394	2.8976
54.86	3.0500	3.0200	1.00	20	42.6	0.325	20	50.4	0.276	0.301	9.211	2.7698
57.91	3.0500	2.7700	1.00	20	42.0	0.329	20	47.2	0.294	0.312	8.449	2.6353
60.96	3.0500	2.6200	1.00	20	47.6	0.292	20	51.8	0.269	0.281	7.991	2.2427
64.01	3.0500	2.5600	1.00	20	48.0	0.290	20	51.0	0.273	0.282	7.808	2.1980
67.06	3.0500	2.3500	1.00	20	49.2	0.283	20	52.0	0.268	0.276	7.167	1.9753
70.10	3.0500	2.1000	1.00	20	50.8	0.274	20	55.8	0.251	0.263	6.405	1.6818
73.15	3.0500	1.9500	1.00	20	49.6	0.281	15	43.8	0.240	0.260	5.947	1.5489
76.20	3.8100	1.8600	1.00	15	42.4	0.248	15	49.8	0.213	0.230	7.087	1.6308
80.77	4.5700	1.8600	1.00	10	42.4	0.169	15	53.0	0.200	0.185	8.500	1.5698
85.34	4.5700	0.8200	0.88	10	40.8	0.154	10	40.8	0.154	0.154	3.747	0.5774
89.92	2.2900	0.0000	1.00	0	0.0	0.000	0	0.0	0.000	0.000	0.000	0.0000

DATE:	86-01-21
TIME:	1425-1535
METER NO:	WSC 6-356
SUSPENSION:	ROD
A1:	0.6679
B1:	0.0114
BREAK IN REV/S:	10.0000
A2:	0.6679
B2:	0.0114
DATE RATED:	84-10-01
RATED AT:	CCIW
RATED ON:	ROD
REMARK:	ORIGINAL
NO. OF VERT.:	28.0000
WIDTH (M):	89.0400
MEAN VEL. (M/S)	0.2676
AREA (SQ. M.):	207 3752
DISCHARGE (CMS)	55.4861

TABLE 3 RED RIVER AT EMERSON,MN JANUARY 22, 1986

1ST MEASUREMENT - WSC1 WITH WSC WINTER METER 6-356 ON ROD

STATION	WIDTH	DEPTH	COEFF	REV 0.2D	TIM 0.2D	VEL 0.2D	REV 0.8D	TIM 0.8D	VEL 0.8D	MEAN VEL.	AREA	FLOW
0	1.5000	0.0000	1.00	0	0.0	0.000	0	0.0	0.000	0.000	0.000	0.0000
3	3.0000	0.8400	0.88	10	39.4	0.159	10	39.4	0.159	0.159	2.520	0.4012
6	3.0000	1.5700	1.00	15	45.4	0.232	15	43.6	0.241	0.237	4.710	1.1145
9	3.0000	1.7000	1.00	15	39.6	0.264	15	49.4	0.214	0.239	5.100	1.2204
12	3.0000	2.1000	1.00	15	39.6	0.264	15	47.0	0.225	0.244	6.300	1.5402
15	3.0000	2.4200	1.00	20	50.4	0.276	15	45.6	0.231	0.254	7.260	1.8424
18	3.0000	2.6000	1.00	20	39.8	0.347	20	49.4	0.282	0.314	7.800	2.4524
21	3.0000	3.0200	1.00	20	40.2	0.344	20	49.0	0.284	0.314	9.060	2.8435
24	3.0000	3.3400	1.00	20	40.0	0.345	20	47.6	0.292	0.319	10.020	3.1933
27	3.0000	3.4300	1.00	22	41.6	0.365	20	45.2	0.307	0.336	10.290	3.4551
30	3.0000	3.4000	1.00	22	41.2	0.368	20	44.0	0.315	0.342	10.200	3.4835
33	3.0000	3.3200	1.00	30	54.8	0.377	20	44.2	0.314	0.345	9.960	3.4395
36	3.0000	3.2800	1.00	30	54.4	0.380	20	49.8	0.280	0.330	9.840	3.2441
39	3.0000	3.2600	1.00	30	52.6	0.392	20	42.6	0.325	0.359	9.780	3.5076
42	3.0000	3.3000	1.00	30	47.6	0.432	20	39.2	0.352	0.392	9.900	3.8833
45	3.0000	3.3800	1.00	30	45.8	0.449	20	41.0	0.337	0.393	10.140	3.9855
48	3.0000	3.2800	1.00	30	45.2	0.455	20	40.8	0.339	0.397	9.840	3.9040
51	3.0000	3.0200	1.00	30	48.4	0.425	30	57.0	0.363	0.394	9.060	3.5711
54	3.0000	2.5200	1.00	30	50.0	0.412	30	59.0	0.351	0.382	7.560	2.8847
57	3.0000	2.6600	1.00	30	57.0	0.363	20	50.6	0.275	0.319	7.980	2.5469
60	3.0000	1.8200	1.00	20	48.2	0.289	20	42.6	0.325	0.307	5.460	1.6749
63	3.0000	1.4000	1.00	15	40.4	0.259	15	39.0	0.268	0.264	4.200	1.1081
66	3.0000	1.0800	1.00	15	52.0	0.204	15	53.0	0.200	0.202	3.240	0.6553
69	2.0000	0.3600	0.88	15	53.6	0.175	15	53.6	0.175	0.175	0.720	0.1257
70	0.5000	0.0000	1.00	0	0.0	0.000	0	0.0	0.000	0.000	0.000	0.0000

DATE:	86-01-22
TIME:	0950-1100
METER NO:	WSC 6-356
SUSPENSION:	ROD
A1:	0.6679
B1:	0.0114
BREAK IN REV/S:	10.0000
A2:	0.6679
B2:	0.0114
DATE RATED:	84-10-01
RATED AT:	CCIW
RATED ON:	ROD
REMARK:	ORIGINAL
NO. OF VERT.:	25.0000
WIDTH (M):	70.0000
MEAN VEL. (M/S)	0.3281
AREA (SQ. M.):	170.9400
DISCHARGE (CMS)	56.0770

TABLE 4 RED RIVER AT EMERSON,MN JANUARY 22, 1986

2ND MEASUREMENT - WSC1 WITH WSC WINTER METER 6-356 ON ROD

STATION	WIDTH	DEPTH	COEFF	REV 0.2D	TIM 0.2D	VEL 0.2D	REV 0.8D	TIM 0.8D	VEL 0.8D	MEAN VEL.	AREA	FLOW
0	1.5000	0.0000	1.00	0	0.0	0.000	0	0.0	0.000	0.000	0.000	0.0000
3	3.0000	0.8400	0.88	10	40.6	0.155	10	40.6	0.155	0.155	2.520	0.3901
6	3.0000	1.5600	1.00	15	44.2	0.238	15	47.4	0.223	0.230	4.680	1.0783
9	3.0000	1.7000	1.00	15	39.2	0.267	15	45.8	0.230	0.249	5.100	1.2677
12	3.0000	2.0800	1.00	15	39.4	0.266	15	44.0	0.239	0.252	6.240	1.5749
15	3.0000	2.4200	1.00	20	50.0	0.279	15	42.4	0.248	0.263	7.260	1.9103
18	3.0000	2.6000	1.00	20	43.4	0.319	15	39.0	0.268	0.294	7.800	2.2911
21	3.0000	3.0200	1.00	20	39.6	0.349	20	48.8	0.285	0.317	9.060	2.8714
24	3.0000	3.3600	1.00	20	42.6	0.325	20	45.0	0.308	0.317	10.080	3.1914
27	3.0000	3.4000	1.00	20	39.0	0.354	20	44.0	0.315	0.334	10.200	3.4114
30	3.0000	3.4200	1.00	20	39.8	0.347	20	39.8	0.347	0.347	10.260	3.5605
33	3.0000	3.3400	1.00	30	52.0	0.397	20	46.8	0.297	0.347	10.020	3.4747
36	3.0000	3.2800	1.00	30	57.0	0.363	20	41.8	0.331	0.347	9.840	3.4140
39	3.0000	3.2000	1.00	30	51.0	0.404	20	48.0	0.290	0.347	9.600	3.3311
42	3.0000	3.2900	1.00	30	52.8	0.391	20	49.4	0.282	0.336	9.870	3.3197
45	3.0000	3.2600	1.00	30	47.8	0.431	20	43.8	0.316	0.373	9.780	3.6526
48	3.0000	3.2800	1.00	30	46.0	0.447	30	59.2	0.350	0.398	9.840	3.9205
51	3.0000	3.0200	1.00	30	45.2	0.455	30	59.6	0.348	0.401	9.060	3.6344
54	3.0000	2.5200	1.00	30	52.0	0.397	20	39.0	0.354	0.375	7.560	2.8374
57	3.0000	2.6400	1.00	30	57.0	0.363	20	46.4	0.299	0.331	7.920	2.6224
60	3.0000	1.8400	1.00	20	44.6	0.311	20	46.0	0.302	0.306	5.520	1.6910
63	3.0000	1.4000	1.00	15	40.0	0.262	15	45.8	0.230	0.246	4.200	1.0332
66	3.0000	1.1000	1.00	20	49.0	0.284	15	49.8	0.213	0.248	3.300	0.8194
69	2.0000	0.3600	0.88	15	46.2	0.201	15	46.2	0.201	0.201	0.720	0.1446
70	0.5000	0.0000	1.00	0	0.0	0.000	0	0.0	0.000	0.000	0.000	0.0000

DATE:	86-01-22
TIME:	1320-1430
METER NO:	WSC 6-356
SUSPENSION:	ROD
A1:	0.6679
B1:	0.0114
BREAK IN REV/S:	10.0000
A2:	0.6679
B2:	0.0114
DATE RATED:	84-10-01
RATED AT:	CCIW
RATED ON:	ROD
REMARK:	ORIGINAL
NO. OF VERT.:	25.0000
WIDTH (M):	70.0000
MEAN VEL. (M/S)	0.3253
AREA (SQ. M.):	170.4300
DISCHARGE (CMS)	55.4421

TABLE 5 RED RIVER AT EMERSON,MN JANUARY 23, 1986
1ST MEASUREMENT - WSC1 WITH WSC WINTER METER 6-356 ON ROD

STATION	WIDTH	DEPTH	COEFF	REV 0.2D	TIM 0.2D	VEL 0.2D	REV 0.8D	TIM 0.8D	VEL 0.8D	MEAN VEL.	AREA	FLOW
0	1.5000	0.0000	1.00	0	0.0	0.000	0	0.0	0.000	0.000	0.000	0.0000
3	3.0000	0.8400	0.88	15	57.0	0.165	15	57.0	0.165	0.165	2.520	0.4151
6	3.0000	1.6000	1.00	15	47.6	0.222	15	46.6	0.226	0.224	4.800	1.0758
9	3.0000	1.7200	1.00	15	40.2	0.261	15	48.4	0.218	0.240	5.160	1.2358
12	3.0000	2.0800	1.00	15	39.0	0.268	15	47.4	0.223	0.246	6.240	1.5321
15	3.0000	2.4300	1.00	20	49.8	0.280	15	40.6	0.258	0.269	7.290	1.9603
18	3.0000	2.6200	1.00	20	42.6	0.325	20	50.4	0.276	0.301	7.860	2.3635
21	3.0000	3.0400	1.00	20	42.0	0.329	20	47.8	0.291	0.310	9.120	2.8286
24	3.0000	3.3500	1.00	20	40.8	0.339	20	44.2	0.314	0.326	10.050	3.2784
27	3.0000	3.4000	1.00	20	40.2	0.344	20	43.0	0.322	0.333	10.200	3.3953
30	3.0000	3.4200	1.00	20	41.8	0.331	20	43.6	0.318	0.324	10.260	3.3281
33	3.0000	3.3200	1.00	30	54.6	0.378	20	42.8	0.324	0.351	9.960	3.4954
36	3.0000	3.2800	1.00	30	53.0	0.389	20	44.8	0.310	0.350	9.840	3.4392
39	3.0000	3.2000	1.00	30	51.2	0.403	30	54.0	0.382	0.393	9.600	3.7690
42	3.0000	3.2800	1.00	30	47.6	0.432	30	54.0	0.382	0.407	9.840	4.0088
45	3.0000	3.3300	1.00	30	46.2	0.445	30	57.4	0.360	0.403	9.990	4.0239
48	3.0000	3.2400	1.00	30	48.0	0.429	20	39.8	0.347	0.388	9.720	3.7707
51	3.0000	3.0600	1.00	30	46.0	0.447	20	42.0	0.329	0.388	9.180	3.5638
54	3.0000	2.5400	1.00	30	54.4	0.380	22	46.0	0.331	0.355	7.620	2.7072
57	3.0000	2.6400	1.00	30	54.6	0.378	20	43.0	0.322	0.350	7.920	2.7737
60	3.0000	1.8200	1.00	20	47.0	0.296	20	45.4	0.306	0.301	5.460	1.6414
63	3.0000	1.4000	1.00	20	50.8	0.274	15	44.6	0.236	0.255	4.200	1.0718
66	3.0000	1.1000	1.00	15	46.4	0.227	15	48.4	0.218	0.223	3.300	0.7354
69	2.0000	0.3500	0.88	10	42.0	0.150	10	42.0	0.150	0.150	0.700	0.1050
70	0.5000	0.0000	1.00	0	0.0	0.000	0	0.0	0.000	0.000	0.000	0.0000

DATE: 86-01-23
TIME: 0845-0955
METER NO: WSC 6-356
SUSPENSION: ROD

A1: 0.6679
B1: 0.0114
BREAK IN REV/S: 10.0000
A2: 0.6679
B2: 0.0114
DATE RATED: 84-10-01
RATED AT: CCIW
RATED ON: ROD
REMARK: ORIGINAL

NO. OF VERT.: 25.0000
WIDTH (M): 70.0000
MEAN VEL. (M/S) 0.3308
AREA (SQ. M.): 170.8300
DISCHARGE (CMS) 56.5182

TABLE 6 RED RIVER AT EMERSON,MN JANUARY 23, 1986

2ND MEASUREMENT - WSC1 WITH WSC WINTER METER 6-356 ON ROD

STATION	WIDTH	DEPTH	COEFF	REV 0.2D	TIM 0.2D	VEL 0.2D	REV 0.8D	TIM 0.8D	VEL 0.8D	MEAN VEL.	AREA	FLOW
0	1.5000	0.0000	1.00	0	0.0	0.000	0	0.0	0.000	0.000	0.000	0.0000
3	3.0000	0.8100	0.88	15	57.2	0.164	15	57.2	0.164	0.164	2.430	0.3989
6	3.0000	1.6100	1.00	15	46.6	0.226	15	48.0	0.220	0.223	4.830	1.0783
9	3.0000	1.7200	1.00	15	39.8	0.263	15	48.2	0.219	0.241	5.160	1.2445
12	3.0000	2.0800	1.00	20	51.2	0.272	15	48.0	0.220	0.246	6.240	1.5363
15	3.0000	2.4200	1.00	20	50.0	0.279	15	43.0	0.244	0.261	7.260	1.8983
18	3.0000	2.6200	1.00	20	46.0	0.302	20	49.4	0.282	0.292	7.860	2.2935
21	3.0000	3.0200	1.00	20	42.2	0.328	20	46.0	0.302	0.315	9.060	2.8527
24	3.0000	3.3400	1.00	20	42.2	0.328	20	48.4	0.287	0.308	10.020	3.0828
27	3.0000	3.3800	1.00	20	42.8	0.324	20	44.6	0.311	0.317	10.140	3.2165
30	3.0000	3.4100	1.00	30	58.8	0.352	30	58.6	0.353	0.353	10.230	3.6086
33	3.0000	3.3400	1.00	30	57.0	0.363	30	58.0	0.357	0.360	10.020	3.6062
36	3.0000	3.2600	1.00	30	52.8	0.391	30	52.8	0.391	0.391	9.780	3.8229
39	3.0000	3.2300	1.00	30	50.0	0.412	30	51.2	0.403	0.407	9.690	3.9481
42	3.0000	3.2800	1.00	30	48.0	0.429	20	39.2	0.352	0.391	9.840	3.8425
45	3.0000	3.2300	1.00	30	46.8	0.440	30	53.0	0.389	0.414	9.690	4.0165
48	3.0000	3.2600	1.00	30	45.0	0.457	30	57.0	0.363	0.410	9.780	4.0078
51	3.0000	3.0200	1.00	30	45.8	0.449	20	41.0	0.337	0.393	9.060	3.5610
54	3.0000	2.5000	1.00	30	51.8	0.398	30	55.2	0.374	0.386	7.500	2.8973
57	3.0000	2.6600	1.00	30	56.0	0.369	20	46.0	0.302	0.335	7.980	2.6773
60	3.0000	1.8200	1.00	20	40.4	0.342	20	45.8	0.303	0.323	5.460	1.7611
63	3.0000	1.3800	1.00	15	41.0	0.256	15	40.8	0.257	0.256	4.140	1.0613
66	3.0000	1.0800	1.00	15	49.4	0.214	15	52.0	0.204	0.209	3.240	0.6776
69	2.0000	0.3500	0.88	10	42.4	0.149	10	42.4	0.149	0.149	0.700	0.1041
70	0.5000	0.0000	1.00	0	0.0	0.000	0	0.0	0.000	0.000	0.000	0.0000

DATE:	86-01-23
TIME:	1005-1115
METER NO:	WSC 6-356
SUSPENSION:	ROD
A1:	0.6679
B1:	0.0114
BREAK IN REV/S:	10.0000
A2:	0.6679
B2:	0.0114
DATE RATED:	84-10-01
RATED AT:	CCIW
RATED ON:	ROD
REMARK:	ORIGINAL
NO. OF VERT.:	25.0000
WIDTH (M):	70.0000
MEAN VEL. (M/S)	0.3362
AREA (SQ. M.):	170.1100
DISCHAPGE (CMS)	57.1941

Measurements with WSC Winter Meter 6-288

TABLE 7. RED RIVER AT DRAYTON, ND JANUARY 21, 1986

1ST MEASUREMENT - WSC2 WITH WSC WINTER METER 6-288 ON ROD

STATION	WIDTH	DEPTH	COEFF	REV 0.2D	TIM 0.2D	VEL 0.2D	REV 0.8D	TIM 0.8D	VEL 0.8D	MEAN VEL.	AREA	FLOW
1.00	1.5000	0.0000	1.00	0	0.0	0.000	0	0.0	0.000	0.000	0.000	0.0000
4.00	3.5000	0.2100	0.88	1	70.0	0.009	1	70.0	0.009	0.009	0.735	0.0063
8.00	4.0000	1.4600	1.00	10	46.2	0.148	10	46.8	0.146	0.147	5.840	0.8591
12.00	4.0000	2.0600	1.00	15	44.4	0.231	15	46.4	0.221	0.226	8.240	1.8631
16.00	4.0000	2.1800	1.00	15	41.0	0.250	20	50.6	0.270	0.260	8.720	2.2698
20.00	4.0000	2.4800	1.00	20	50.2	0.273	20	51.0	0.268	0.270	9.920	2.6821
24.00	4.0000	2.6500	1.00	15	40.2	0.255	15	43.0	0.239	0.247	10.600	2.6173
28.00	4.0000	2.6800	1.00	20	49.4	0.277	15	42.8	0.240	0.258	10.720	2.7692
32.00	4.0000	3.0000	1.00	20	50.0	0.274	15	40.8	0.251	0.263	12.000	3.1504
36.00	4.0000	3.1500	1.00	20	46.6	0.294	15	39.2	0.262	0.278	12.600	3.4984
40.00	4.0000	3.2100	1.00	20	46.2	0.296	20	50.0	0.274	0.285	12.840	3.6575
44.00	4.0000	3.1900	1.00	20	44.8	0.305	20	44.0	0.311	0.308	12.760	3.9318
48.00	4.0000	3.2200	1.00	20	42.6	0.321	20	48.0	0.285	0.303	12.880	3.9035
52.00	4.0000	3.0600	1.00	20	44.2	0.310	20	47.4	0.289	0.299	12.240	3.6604
56.00	4.0000	2.8200	1.00	20	44.8	0.305	15	39.0	0.263	0.284	11.280	3.2060
60.00	4.0000	2.6800	1.00	20	45.6	0.300	20	48.2	0.284	0.292	10.720	3.1293
64.00	4.0000	2.7100	1.00	20	47.0	0.291	15	40.8	0.251	0.271	10.840	2.9405
68.00	4.0000	2.5000	1.00	20	48.4	0.283	15	41.0	0.250	0.266	10.000	2.6644
72.00	4.0000	2.3400	1.00	20	49.2	0.278	15	40.0	0.257	0.267	9.360	2.5017
76.00	4.0000	2.1500	1.00	20	50.4	0.271	15	41.4	0.248	0.260	8.600	2.2328
80.00	4.0000	0.9100	0.88	15	39.4	0.229	15	39.4	0.229	0.229	3.640	0.8341
84.00	4.0000	1.4800	1.00	15	48.6	0.211	15	53.8	0.191	0.201	5.920	1.1894
88.00	3.0000	0.4900	0.88	10	54.0	0.111	10	54.0	0.111	0.111	1.470	0.1639
90.00	1.0000	0.0000	1.00	0	0.0	0.000	0	0.0	0.000	0.000	0.000	0.0000

DATE:	86-01-21
TIME:	1100-1200
METER NO:	WSC 6-288
SUSPENSION:	ROD
A1:	0.6840
B1:	0.0000
BREAK IN REV/S:	10.0000
A2:	0.6840
B2:	0.0000
DATE RATED:	84-08-23
RATED AT:	CCIW
RATED ON:	ROD
REMARK:	ORIGINAL
NO. OF VERT.:	24.0000
WIDTH (M):	89.0000
MEAN VEL. (M/S)	0.2661
AREA (SQ. M.):	201.9250
DISCHARGE (CMS)	53.7309

TABLE 8. RED RIVER AT DRAYTON, ND JANUARY 21, 1986

2ND MEASUREMENT - WSC2 WITH WSC WINTER METER 6-288 ON ROD

STATION	WIDTH	DEPTH	COEFF	REV 0.2D	TIM 0.2D	VEL 0.2D	REV 0.8D	TIM 0.8D	VEL 0.8D	MEAN VEL.	AREA	FLOW
1.00	1.5000	0.0000	1.00	0	0.0	0.000	0	0.0	0.000	0.000	0.000	0.0000
4.00	3.5000	0.2400	0.88	1	70.0	0.009	1	70.0	0.009	0.009	0.840	0.0072
8.00	4.0000	1.4600	1.00	10	44.0	0.155	10	49.8	0.137	0.146	5.840	0.8550
12.00	4.0000	2.0600	1.00	15	44.6	0.230	15	51.2	0.200	0.215	8.240	1.7734
16.00	4.0000	2.1700	1.00	15	39.2	0.262	15	43.8	0.234	0.248	8.680	2.1526
20.00	4.0000	2.4800	1.00	20	48.8	0.280	15	41.4	0.248	0.264	9.920	2.6196
24.00	4.0000	2.6000	1.00	20	47.4	0.289	15	40.2	0.255	0.272	10.400	2.8279
28.00	4.0000	2.6600	1.00	20	50.6	0.270	20	52.2	0.262	0.266	10.640	2.8325
32.00	4.0000	2.9100	1.00	20	47.2	0.290	20	50.0	0.274	0.282	11.640	3.2792
36.00	4.0000	3.0600	1.00	20	45.6	0.300	20	50.6	0.270	0.285	12.240	3.4906
40.00	4.0000	3.1800	1.00	20	45.0	0.304	20	53.8	0.254	0.279	12.720	3.5506
44.00	4.0000	3.2100	1.00	20	43.6	0.314	20	49.2	0.278	0.296	12.840	3.7994
48.00	4.0000	3.2000	1.00	20	42.4	0.323	20	49.4	0.277	0.300	12.800	3.8372
52.00	4.0000	3.0600	1.00	20	42.8	0.320	20	43.6	0.314	0.317	12.240	3.8763
56.00	4.0000	2.8200	1.00	20	42.6	0.321	20	49.6	0.276	0.298	11.280	3.3667
60.00	4.0000	2.6600	1.00	20	44.0	0.311	20	47.2	0.290	0.300	10.640	3.1959
64.00	4.0000	2.7200	1.00	20	43.6	0.314	20	51.4	0.266	0.290	10.880	3.1547
68.00	4.0000	2.5200	1.00	20	48.0	0.285	15	39.8	0.258	0.271	10.080	2.7357
72.00	4.0000	2.3200	1.00	20	51.0	0.268	20	49.8	0.275	0.271	9.280	2.5192
76.00	3.0000	2.1700	1.00	20	51.6	0.265	15	43.2	0.238	0.251	6.510	1.6360
78.00	2.0000	2.0600	1.00	20	52.4	0.261	15	43.2	0.238	0.249	4.120	1.0271
80.00	2.0000	0.9700	0.88	15	39.2	0.230	15	39.2	0.230	0.230	1.940	0.4468
82.00	2.0000	1.0400	1.00	15	42.8	0.240	10	51.0	0.134	0.187	2.080	0.3888
84.00	3.0000	1.4900	1.00	15	48.4	0.212	15	51.6	0.199	0.205	4.470	0.9182
88.00	3.0000	0.5100	0.88	10	52.8	0.114	10	52.8	0.114	0.114	1.530	0.1744
90.00	1.0000	0.0000	1.00	0	0.0	0.000	0	0.0	0.000	0.000	0.000	0.0000

DATE:	86-01-21
TIME:	1405-1510
METER NO:	WSC 6-288
SUSPENSION:	ROD
A1:	0.6840
B1:	0.0000
BREAK IN REV/S:	10.0000
A2:	0.6840
B2:	0.0000
DATE RATED:	84-08-23
RATED AT:	CCIW
RATED ON:	ROD
REMARK:	ORIGINAL
NO. OF VERT.:	26.0000
WIDTH (M):	89.0000
MEAN VEL. (M/S)	0.2698
AREA (SQ. M.):	201.8500
DISCHARGE (CMS)	54.4651

TABLE 9. RED RIVER AT DRAYTON, ND JANUARY 21, 1986

3RD MEASUREMENT - WSC2 WITH WSC WINTER METER 6-288 ON ROD

STATION	WIDTH	DEPTH	COEFF	REV 0.2D	TIM 0.2D	VEL 0.2D	REV 0.8D	TIM 0.8D	VEL 0.8D	MEAN VEL.	AREA	FLOW
1.00	1.5000	0.0000	1.00	0	0.0	0.000	0	0.0	0.000	0.000	0.000	0.0000
4.00	3.5000	0.2100	0.88	1	70.0	0.009	1	70.0	0.009	0.009	0.735	0.0063
8.00	4.0000	1.4300	1.00	10	43.0	0.159	10	53.6	0.128	0.143	5.720	0.8199
12.00	4.0000	2.0300	1.00	15	43.6	0.235	15	48.6	0.211	0.223	8.120	1.8125
16.00	4.0000	2.1800	1.00	15	39.6	0.259	15	44.2	0.232	0.246	8.720	2.1417
20.00	4.0000	2.4700	1.00	15	39.0	0.263	15	41.6	0.247	0.255	9.880	2.5180
24.00	4.0000	2.6300	1.00	20	49.0	0.279	15	46.0	0.223	0.251	10.520	2.6417
28.00	4.0000	2.6800	1.00	20	49.0	0.279	15	44.2	0.232	0.256	10.720	2.7406
32.00	4.0000	3.0000	1.00	20	46.6	0.294	15	43.6	0.235	0.264	12.000	3.1733
36.00	4.0000	3.1400	1.00	20	46.6	0.294	15	43.4	0.236	0.265	12.560	3.3282
40.00	4.0000	3.1800	1.00	20	46.0	0.297	15	39.2	0.262	0.280	12.720	3.5560
44.00	4.0000	3.2000	1.00	20	45.0	0.304	20	48.6	0.281	0.293	12.800	3.7471
48.00	4.0000	3.1900	1.00	20	44.0	0.311	20	48.8	0.280	0.296	12.760	3.7721
52.00	4.0000	3.0700	1.00	20	42.0	0.326	20	47.2	0.290	0.308	12.280	3.7794
56.00	4.0000	2.8400	1.00	20	41.8	0.327	20	46.4	0.295	0.311	11.360	3.5335
60.00	4.0000	2.6800	1.00	20	47.4	0.289	20	46.4	0.295	0.292	10.720	3.1272
64.00	4.0000	2.7200	1.00	20	48.4	0.283	20	46.4	0.295	0.289	10.880	3.1414
68.00	4.0000	2.5100	1.00	20	47.4	0.289	20	51.0	0.268	0.278	10.040	2.7954
72.00	4.0000	2.3500	1.00	20	50.2	0.273	20	52.0	0.263	0.268	9.400	2.5173
76.00	3.0000	2.1700	1.00	15	39.6	0.259	15	40.0	0.257	0.258	6.510	1.6782
78.00	2.0000	2.0300	1.00	15	39.8	0.258	15	43.8	0.234	0.246	4.060	0.9988
80.00	2.0000	0.9300	0.88	15	39.8	0.227	15	39.8	0.227	0.227	1.860	0.4219
82.00	2.0000	1.0600	1.00	15	43.6	0.235	10	48.6	0.141	0.188	2.120	0.3986
84.00	3.0000	1.4900	1.00	15	49.2	0.209	15	53.4	0.192	0.200	4.470	0.8955
88.00	3.0000	0.5100	0.88	10	55.8	0.108	10	55.8	0.108	0.108	1.530	0.1650
90.00	1.0000	0.0000	1.00	0	0.0	0.000	0	0.0	0.000	0.000	0.000	0.0000

DATE:	86-01-21
TIME:	1515-1610
METER NO:	WSC 6-288
SUSPENSION:	ROD
A1:	0.6840
B1:	0.0000
BREAK IN REV/S:	10.0000
A2:	0.6840
B2:	0.0000
DATE RATED:	84-08-23
RATED AT:	CCIW
RATED ON:	ROD
REMARK:	ORIGINAL
NO. OF VERT.:	26.0000
WIDTH (M):	89.0000
MEAN VEL. (M/S)	0.2653
AREA (SQ. M.):	202.4850
DISCHARGE (CMS)	53.7099

TABLE 10. RED RIVER AT EMERSON, MN JANUARY 22, 1986
1ST MEASUREMENT - WSC2 WITH WSC WINTER METER 6-288 ON ROD

STATION	WIDTH	DEPTH	COEFF	REV 0.2D	TIM 0.2D	VEL 0.2D	REV 0.8D	TIM 0.8D	VEL 0.8D	MEAN VEL.	AREA	FLOW
5	1.0000	0.0000	1.00	0	0.0	0.000	0	0.0	0.000	0.000	0.000	0.0000
7	2.5000	0.3300	0.88	10	68.4	0.088	10	68.4	0.088	0.088	0.825	0.0726
10	3.0000	1.2200	1.00	10	42.0	0.163	10	44.2	0.155	0.159	3.660	0.5812
13	3.0000	1.6500	1.00	15	48.6	0.211	15	49.6	0.207	0.209	4.950	1.0345
16	3.0000	1.8100	1.00	15	47.0	0.218	15	49.6	0.207	0.213	5.430	1.1543
19	3.0000	1.9300	1.00	15	44.6	0.230	15	47.8	0.215	0.222	5.790	1.2874
22	3.0000	2.1600	1.00	15	41.6	0.247	15	53.0	0.194	0.220	6.480	1.4263
25	3.0000	2.4000	1.00	20	47.2	0.290	15	43.8	0.234	0.262	7.200	1.8867
28	3.0000	2.8400	1.00	20	44.8	0.305	20	51.0	0.268	0.287	8.520	2.4435
31	3.0000	3.2300	1.00	20	43.8	0.312	15	45.0	0.228	0.270	9.690	2.6179
34	3.0000	3.7000	1.00	20	43.0	0.318	20	43.8	0.312	0.315	11.100	3.4991
37	3.0000	3.9400	1.00	20	42.2	0.324	20	41.6	0.329	0.327	11.820	3.8593
40	3.0000	3.7700	1.00	20	39.2	0.349	20	41.0	0.334	0.341	11.310	3.8603
43	3.0000	3.9300	1.00	20	40.0	0.342	15	39.0	0.263	0.303	11.790	3.5669
46	3.0000	3.8700	1.00	25	46.8	0.365	20	45.0	0.304	0.335	11.610	3.8858
49	3.0000	3.8200	1.00	30	47.4	0.433	20	44.2	0.310	0.371	11.460	4.2540
52	3.0000	3.7200	1.00	30	46.0	0.446	25	47.0	0.364	0.405	11.160	4.5193
55	3.0000	3.8300	1.00	30	44.2	0.464	25	44.0	0.389	0.426	11.490	4.8999
58	3.0000	3.2400	1.00	30	48.6	0.422	20	39.8	0.344	0.383	9.720	3.7225
61	3.0000	2.9800	1.00	25	44.2	0.387	15	41.4	0.248	0.317	8.940	2.8371
64	3.0000	2.7400	1.00	20	46.4	0.295	15	39.4	0.260	0.278	8.220	2.2820
67	3.0000	1.5900	1.00	15	48.4	0.212	15	51.6	0.199	0.205	4.770	0.9798
70	3.0000	0.7500	0.88	8	50.8	0.095	8	50.8	0.095	0.095	2.250	0.2133
73	3.0000	0.4500	0.88	10	56.4	0.107	10	56.4	0.107	0.107	1.350	0.1441
76	1.5000	0.0000	1.00	0	0.0	0.000	0	0.0	0.000	0.000	0.000	0.0000

DATE: 86-01-22
TIME: 0940-1050
METER NO: WSC 6-288
SUSPENSION: ROD

A1: 0.6840
B1: 0.0000
BREAK IN REV/S: 10.0000
A2: 0.6840
B2: 0.0000
DATE RATED: 84-08-23
RATED AT: CCIW
RATED ON: ROD
REMARK: ORIGINAL

NO. OF VERT.: 25.0000
WIDTH (M): 71.0000
MEAN VEL. (M/S) 0.3065
AREA (SQ. M.): 179.5350
DISCHARGE (CMS) 55.0278

TABLE 11. RED RIVER AT EMERSON, MN JANUARY 22, 1986

2ND MEASUREMENT - WSC2 WITH WSC WINTER METER 6-288 ON ROD

STATION	WIDTH	DEPTH	COEFF	REV 0.2D	TIM 0.2D	VEL 0.2D	REV 0.8D	TIM 0.8D	VEL 0.8D	MEAN VEL.	AREA	FLOW
5	1.0000	0.0000	1.00	0	0.0	0.000	0	0.0	0.000	0.000	0.000	0.0000
7	2.5000	0.3100	0.88	8	56.8	0.085	8	56.8	0.085	0.085	0.775	0.0657
10	3.0000	1.2200	1.00	15	57.0	0.180	10	45.4	0.151	0.165	3.660	0.6051
13	3.0000	1.6500	1.00	15	45.6	0.225	15	55.2	0.186	0.205	4.950	1.0169
16	3.0000	1.7900	1.00	15	41.8	0.245	15	45.2	0.227	0.236	5.370	1.2685
19	3.0000	1.9200	1.00	15	42.2	0.243	15	48.0	0.214	0.228	5.760	1.3158
22	3.0000	2.0800	1.00	15	41.6	0.247	15	48.2	0.213	0.230	6.240	1.4336
25	3.0000	2.5000	1.00	20	47.4	0.289	15	45.4	0.226	0.257	7.500	1.9297
28	3.0000	2.8500	1.00	20	45.0	0.304	15	46.4	0.221	0.263	8.550	2.2449
31	3.0000	3.2400	1.00	20	43.6	0.314	15	42.0	0.244	0.279	9.720	2.7121
34	3.0000	3.7000	1.00	20	44.0	0.311	20	46.2	0.296	0.304	11.100	3.3689
37	3.0000	3.9100	1.00	20	39.8	0.344	20	41.8	0.327	0.335	11.730	3.9354
40	3.0000	3.9400	1.00	20	42.0	0.326	20	43.6	0.314	0.320	11.820	3.7793
43	3.0000	3.9800	1.00	20	39.6	0.345	20	40.8	0.335	0.340	11.940	4.0641
46	3.0000	3.8800	1.00	25	43.4	0.394	20	42.2	0.324	0.359	11.640	4.1798
49	3.0000	3.8200	1.00	30	49.0	0.419	20	40.8	0.335	0.377	11.460	4.3208
52	3.0000	3.7600	1.00	30	44.4	0.462	25	44.4	0.385	0.424	11.280	4.7788
55	3.0000	3.8200	1.00	30	42.2	0.486	25	48.8	0.350	0.418	11.460	4.7941
58	3.0000	3.2300	1.00	25	43.8	0.390	25	46.8	0.365	0.378	9.690	3.6618
61	3.0000	2.9900	1.00	25	44.0	0.389	20	47.4	0.289	0.339	8.970	3.0374
64	3.0000	2.7700	1.00	20	52.0	0.263	15	51.4	0.200	0.231	8.310	1.9225
67	3.0000	1.6200	1.00	15	54.8	0.187	15	56.2	0.183	0.185	4.860	0.8986
70	3.0000	0.7300	0.88	10	51.6	0.117	10	51.6	0.117	0.117	2.190	0.2555
73	3.0000	0.4300	0.88	10	53.0	0.114	10	53.0	0.114	0.114	1.290	0.1465
76	1.5000	0.0000	1.00	0	0.0	0.000	0	0.0	0.000	0.000	0.000	0.0000

DATE:	86-01-22
TIME:	1300-1420
METER NO:	WSC 6-288
SUSPENSION:	ROD
A1:	0.6840
B1:	0.0000
BREAK IN REV/S:	10.0000
A2:	0.6840
B2:	0.0000
DATE RATED:	84-08-23
RATED AT:	CCIW
RATED ON:	ROD
REMARK:	ORIGINAL
NO. OF VERT.:	25.0000
WIDTH (M):	71.0000
MEAN VEL. (M/S)	0.3092
AREA (SQ. M.):	180.2650
DISCHARGE (CMS)	55.7358

TABLE 12. RED RIVER AT EMERSON, MN JANUARY 23, 1986

1ST MEASUREMENT - WSC2 WITH WSC WINTER METER 6-288 ON CABLE

STATION	WIDTH	DEPTH	COEFF	REV 0.2D	TIM 0.2D	VEL 0.2D	REV 0.8D	TIM 0.8D	VEL 0.8D	MEAN VEL.	AREA	FLOW
0	1.5000	0.0000	1.00	0	0.0	0.000	0	0.0	0.000	0.000	0.000	0.0000
3	3.0000	0.8800	0.88	10	47.8	0.126	10	47.8	0.126	0.126	2.640	0.3324
6	3.0000	1.5800	1.00	15	49.0	0.209	10	47.8	0.143	0.176	4.740	0.8354
9	3.0000	1.7100	1.00	15	41.0	0.250	10	55.6	0.123	0.187	5.130	0.9574
12	3.0000	2.0800	1.00	20	50.6	0.270	15	47.8	0.215	0.243	6.240	1.5132
15	3.0000	2.4200	1.00	20	50.4	0.271	15	52.4	0.196	0.234	7.260	1.6960
18	3.0000	2.6200	1.00	20	45.4	0.301	15	40.2	0.255	0.278	7.860	2.1872
21	3.0000	3.0200	1.00	20	40.4	0.339	15	46.0	0.223	0.281	9.060	2.5443
24	3.0000	3.3400	1.00	20	40.0	0.342	20	45.4	0.301	0.322	10.020	3.2230
27	3.0000	3.3800	1.00	25	48.8	0.350	20	48.2	0.284	0.317	10.140	3.2155
30	3.0000	3.3900	1.00	20	39.8	0.344	20	45.6	0.300	0.322	10.170	3.2733
33	3.0000	3.3300	1.00	20	39.2	0.349	20	41.0	0.334	0.341	9.990	3.4098
36	3.0000	3.2600	1.00	25	47.8	0.358	20	52.2	0.262	0.310	9.780	3.0309
39	3.0000	3.2000	1.00	30	48.2	0.426	25	48.2	0.355	0.390	9.600	3.7464
42	3.0000	3.2700	1.00	30	50.4	0.407	20	40.4	0.339	0.373	9.810	3.6579
45	3.0000	3.2400	1.00	30	50.6	0.406	25	47.8	0.358	0.382	9.720	3.7095
48	3.0000	3.2500	1.00	30	47.2	0.435	20	48.2	0.284	0.359	9.750	3.5030
51	3.0000	3.0200	1.00	30	49.8	0.412	20	40.2	0.340	0.376	9.060	3.4081
54	3.0000	2.5300	1.00	25	47.0	0.364	20	41.8	0.327	0.346	7.590	2.6227
57	3.0000	2.6100	1.00	20	44.6	0.307	20	47.2	0.290	0.298	7.830	2.3355
60	3.0000	1.7700	1.00	15	42.8	0.240	15	42.0	0.244	0.242	5.310	1.2850
63	3.0000	1.3900	1.00	15	55.8	0.184	10	43.0	0.159	0.171	4.170	0.7150
66	3.0000	1.0700	0.88	15	53.6	0.168	15	53.6	0.168	0.168	3.210	0.5407
69	2.0000	0.3400	0.88	10	56.6	0.106	10	56.6	0.106	0.106	0.680	0.0723
70	0.5000	0.0000	1.00	0	0.0	0.000	0	0.0	0.000	0.000	0.000	0.0000

DATE:	86-01-23
TIME:	0855-1010
METER NO:	WSC 6-288
SUSPENSION:	CABLE
A1:	0.6840
B1:	0.0000
BREAK IN REV/S:	10.0000
A2:	0.6840
B2:	0.0000
DATE RATED:	84-08-23
RATED AT:	CCIW
RATED ON:	ROD
REMARK:	ORIGINAL
NO. OF VERT.:	25.0000
WIDTH (M):	70.0000
MEAN VEL. (M/S)	0.3052
AREA (SQ. M.):	169.7600
DISCHARGE (CMS)	51.8149

TABLE 13. RED RIVER AT EMERSON, MN JANUARY 23, 1986

2ND MEASUREMENT - WSC2 WITH WSC WINTER METER 6-288 ON CABLE

STATION	WIDTH	DEPTH	COEFF	REV 0.2D	TIM 0.2D	VEL 0.2D	REV 0.8D	TIM 0.8D	VEL 0.8D	MEAN VEL.	AREA	FLOW
0	1.5000	0.0000	1.00	0	0.0	0.000	0	0.0	0.000	0.000	0.000	0.0000
3	3.0000	0.8800	0.88	10	46.0	0.131	10	46.0	0.131	0.131	2.640	0.3454
6	3.0000	1.5800	1.00	15	47.0	0.218	15	54.0	0.190	0.204	4.740	0.9677
9	3.0000	1.7300	1.00	15	42.4	0.242	15	53.2	0.193	0.217	5.190	1.1284
12	3.0000	2.0800	1.00	15	42.0	0.244	15	50.2	0.204	0.224	6.240	1.3998
15	3.0000	2.4300	1.00	20	54.4	0.251	15	47.6	0.216	0.234	7.290	1.7023
18	3.0000	2.6100	1.00	20	48.6	0.281	15	42.0	0.244	0.263	7.830	2.0584
21	3.0000	3.0500	1.00	20	44.0	0.311	15	47.4	0.216	0.264	9.150	2.4127
24	3.0000	3.3500	1.00	20	43.6	0.314	20	50.0	0.274	0.294	10.050	2.9515
27	3.0000	3.4000	1.00	20	43.6	0.314	20	44.4	0.308	0.311	10.200	3.1715
30	3.0000	3.4000	1.00	20	41.2	0.332	20	47.4	0.289	0.310	10.200	3.1653
33	3.0000	3.3200	1.00	25	49.0	0.349	20	46.2	0.296	0.323	9.960	3.2125
36	3.0000	3.3000	1.00	25	49.4	0.346	15	40.6	0.253	0.299	9.900	2.9644
39	3.0000	3.1800	1.00	25	44.6	0.383	20	39.8	0.344	0.364	9.540	3.4684
42	3.0000	3.2800	1.00	30	50.0	0.410	20	45.0	0.304	0.357	9.840	3.5148
45	3.0000	3.2400	1.00	25	42.8	0.400	25	47.4	0.361	0.380	9.720	3.6950
48	3.0000	3.2800	1.00	25	43.8	0.390	20	43.4	0.315	0.353	9.840	3.4716
51	3.0000	3.0500	1.00	30	52.6	0.390	25	48.6	0.352	0.371	9.150	3.3945
54	3.0000	2.5200	1.00	30	49.6	0.414	20	49.6	0.276	0.345	7.560	2.6064
57	3.0000	2.6300	1.00	20	41.8	0.327	20	49.8	0.275	0.301	7.890	2.3748
60	3.0000	1.8200	1.00	20	47.8	0.286	20	52.0	0.263	0.275	5.460	1.4995
63	3.0000	1.4100	1.00	15	46.2	0.222	15	47.2	0.217	0.220	4.230	0.9294
66	3.0000	1.1000	0.88	10	60.0	0.100	10	60.0	0.100	0.100	3.300	0.3311
69	2.0000	0.3400	0.88	10	57.6	0.105	10	57.6	0.105	0.105	0.680	0.0711
70	0.5000	0.0000	1.00	0	0.0	0.000	0	0.0	0.000	0.000	0.000	0.0000

DATE:	86-01-23
TIME:	1015-1125
METER NO:	WSC 6-288
SUSPENSION:	CABLE
A1:	0.6840
B1:	0.0000
BREAK IN REV/S:	10.0000
A2:	0.6840
B2:	0.0000
DATE RATED:	84-08-23
RATED AT:	CCIW
RATED ON:	ROD
REMARK:	ORIGINAL
NO. OF VERT.:	25.0000
WIDTH (M):	70.0000
MEAN VEL. (M/S)	0.2980
AREA (SQ. M.):	170.6000
DISCHARGE (CMS)	50.8365

Measurements with USGS Vane Ice Meter I-39

TABLE 14. RED RIVER AT DRAYTON, ND JANUARY 21, 1986
1ST MEASUREMENT - USGS WITH ICE VANE METER I-39 ON ROD

STATION	WIDTH	DEPTH	COEFF	REV 0.2D	TIM 0.2D	VEL 0.2D	REV 0.8D	TIM 0.8D	VEL 0.8D	MEAN VEL.	AREA	FLOW
0.91	1.8300	0.0000	1	0	0	0.000	0	0	0.000	0.000	0.000	0.0000
4.57	4.1100	0.8200	1	7	51	0.100	5	42	0.087	0.094	3.370	0.3156
9.14	3.8100	2.1600	1	15	44	0.243	15	49	0.219	0.231	8.230	1.9026
12.19	3.0500	2.2600	1	15	40	0.267	15	47	0.228	0.248	6.893	1.7079
15.24	3.0500	2.4700	1	15	40	0.267	15	42	0.255	0.261	7.533	1.9674
18.29	3.0500	2.6200	1	15	40	0.267	15	45	0.238	0.253	7.991	2.0199
21.34	3.0500	2.8700	1	20	50	0.285	15	43	0.249	0.267	8.754	2.3374
24.38	3.0500	2.9300	1	20	48	0.297	15	40	0.267	0.282	8.936	2.5210
27.43	3.0500	3.0200	1	20	50	0.285	15	42	0.255	0.270	9.211	2.4865
30.48	3.0500	2.9900	1	20	48	0.297	20	49	0.291	0.294	9.119	2.6791
33.53	3.0500	2.9300	1	20	45	0.314	20	49	0.291	0.303	8.936	2.7042
36.58	3.0500	2.9000	1	20	44	0.321	20	47	0.302	0.311	8.845	2.7547
39.62	3.0500	3.1700	1	20	47	0.302	20	50	0.285	0.293	9.668	2.8360
42.67	3.0500	3.1700	1	20	43	0.328	20	50	0.285	0.307	9.668	2.9656
45.72	3.0500	3.1400	1	20	45	0.314	20	47	0.302	0.308	9.577	2.9499
48.77	3.0500	3.0800	1	20	45	0.314	20	50	0.285	0.300	9.394	2.8157
51.82	3.0500	3.0800	1	20	47	0.302	20	49	0.291	0.296	9.394	2.7825
54.86	3.0500	3.0500	1	20	46	0.308	20	51	0.280	0.294	9.302	2.7321
57.91	3.0500	2.7700	1	20	45	0.314	20	51	0.280	0.297	8.449	2.5090
60.96	3.0500	2.6500	1	20	46	0.308	20	51	0.280	0.294	8.082	2.3738
64.01	3.0500	2.5900	1	20	47	0.302	20	50	0.285	0.293	7.900	2.3171
67.06	3.0500	2.3800	1	20	46	0.308	15	40	0.267	0.288	7.259	2.0881
70.10	3.0500	2.1300	1	20	48	0.297	15	40	0.267	0.282	6.496	1.8327
73.15	3.0500	1.9500	1	15	40	0.267	15	43	0.249	0.258	5.947	1.5358
76.20	3.8100	1.8900	1	15	44	0.243	15	48	0.223	0.233	7.201	1.6809
80.77	4.5700	1.8900	1	10	40	0.179	15	46	0.233	0.206	8.637	1.7811
85.34	4.5700	0.8200	1	10	52	0.139	7	40	0.127	0.133	3.747	0.4973
89.92	2.2900	0.0000	1	0	0	0.000	0	0	0.000	0.000	0.000	0.0000

DATE:	86-01-21
TIME:	1055-1230
METER NO:	USGS I-39
SUSPENSION:	ROD
A1:	0.7041
B1:	0.0034
BREAK IN REV/S:	0.4255
A2:	0.6773
B2:	0.0134
DATE RATED:	1976-81
RATED AT:	HIF
RATED ON:	ROD
REMARK:	ORIGINAL
NO. OF VERT.:	28.0000
WIDTH (M):	89.0400
MEAN VEL. (M/S)	0.2738
AREA (SQ. M.):	208.5429
DISCHARGE (CMS)	57.0941

TABLE 15. RED RIVER AT DRAYTON, ND JANUARY 21, 1986

2ND MEASUREMENT - USGS WITH ICE VANE METER I-39 ON ROD

STATION	WIDTH	DEPTH	COEFF	REV 0.2D	TIM 0.2D	VEL 0.2D	REV 0.8D	TIM 0.8D	VEL 0.8D	MEAN VEL.	AREA	FLOW
0.91	1.8300	0.0000	1	0	0	0.000	0	0	0.000	0.000	0.000	0.0000
4.57	4.1100	0.7900	1	7	47	0.108	7	49	0.104	0.106	3.247	0.3446
9.14	3.8100	2.1600	1	15	43	0.249	15	50	0.215	0.232	8.230	1.9078
12.19	3.0500	2.2600	1	15	40	0.267	15	44	0.243	0.255	6.893	1.7607
15.24	3.0500	2.4700	1	15	40	0.267	15	45	0.238	0.253	7.533	1.9042
18.29	3.0500	2.6200	1	20	49	0.291	20	52	0.274	0.282	7.991	2.2574
21.34	3.0500	2.8700	1	20	51	0.280	20	52	0.274	0.277	8.754	2.4235
24.38	3.0500	2.9000	1	20	51	0.280	15	42	0.255	0.267	8.845	2.3633
27.43	3.0500	2.9900	1	20	50	0.285	15	40	0.267	0.276	9.119	2.5192
30.48	3.0500	2.9900	1	20	47	0.302	15	41	0.261	0.281	9.119	2.5654
33.53	3.0500	2.9000	1	20	44	0.321	20	47	0.302	0.311	8.845	2.7547
36.58	3.0500	2.9000	1	20	48	0.297	20	50	0.285	0.291	8.845	2.5731
39.62	3.0500	3.1700	1	20	45	0.314	20	48	0.297	0.306	9.668	2.9547
42.67	3.0500	3.1700	1	20	44	0.321	20	47	0.302	0.311	9.668	3.0111
45.72	3.0500	3.1100	1	20	44	0.321	15	40	0.267	0.294	9.485	2.7921
48.77	3.0500	3.0800	1	20	47	0.302	20	46	0.308	0.305	9.394	2.8628
51.82	3.0500	3.0800	1	20	43	0.328	20	51	0.280	0.304	9.394	2.8555
54.86	3.0500	3.0200	1	20	45	0.314	20	51	0.280	0.297	9.211	2.7354
57.91	3.0500	2.7700	1	20	45	0.314	20	50	0.285	0.300	8.449	2.5323
60.96	3.0500	2.6200	1	20	46	0.308	15	40	0.267	0.288	7.991	2.2987
64.01	3.0500	2.5600	1	20	48	0.297	15	40	0.267	0.282	7.808	2.2027
67.06	3.0500	2.3500	1	15	40	0.267	15	41	0.261	0.264	7.167	1.8938
70.10	3.0500	2.1000	1	15	40	0.267	15	44	0.243	0.255	6.405	1.6361
73.15	3.0500	1.9500	1	15	40	0.267	15	40	0.267	0.267	5.947	1.5906
76.20	3.8100	1.8600	1	15	43	0.249	15	43	0.249	0.249	7.087	1.7647
80.77	4.5700	1.8600	1	10	40	0.179	15	50	0.215	0.197	8.500	1.6748
85.34	4.5700	0.8200	1	10	54	0.134	7	40	0.127	0.130	3.747	0.4879
89.92	2.2900	0.0000	1	0	0	0.000	0	0	0.000	0.000	0.000	0.0000

DATE:	86-01-21
TIME:	1440-1545
METER NO:	USGS I-39
SUSPENSION:	ROD
A1:	0.7041
B1:	0.0034
BREAK IN REV/S:	0.4255
A2:	0.6773
B2:	0.0134
DATE RATED:	1976-81
RATED AT:	HIF
RATED ON:	ROD
REMARK:	ORIGINAL
NO. OF VERT.:	28.0000
WIDTH (M):	89.0400
MEAN VEL. (M/S)	0.2733
AREA (SQ. M.):	207.3447
DISCHARGE (CMS)	56.6669

TABLE 16. RED RIVER AT EMERSON, MN JANUARY 22, 1986

1ST MEASUREMENT - USGS WITH ICE VANE METER I-39 ON ROD

STATION	WIDTH	DEPTH	COEFF	REV 0.2D	TIM 0.2D	VEL 0.2D	REV 0.8D	TIM 0.8D	VEL 0.8D	MEAN VEL.	AREA	FLOW
0	1.5000	0.0000	1.00	0	0	0.000	0	0	0.000	0.000	0.000	0.0000
3	3.0000	0.8534	1.00	10	43	0.167	10	40	0.179	0.173	2.560	0.4437
6	3.0000	1.6154	1.00	15	46	0.233	15	50	0.215	0.224	4.846	1.0847
9	3.0000	1.7374	1.00	15	47	0.228	15	41	0.261	0.245	5.212	1.2746
12	3.0000	2.1031	1.00	15	40	0.267	15	49	0.219	0.243	6.309	1.5344
15	3.0000	2.4384	1.00	20	50	0.285	15	43	0.249	0.267	7.315	1.9534
18	3.0000	2.6518	1.00	20	45	0.314	20	49	0.291	0.303	7.955	2.4073
21	3.0000	3.0785	1.00	20	42	0.336	20	47	0.302	0.319	9.235	2.9440
24	3.0000	3.3833	1.00	20	40	0.352	20	44	0.321	0.337	10.150	3.4170
27	3.0000	3.4747	1.00	20	41	0.344	20	46	0.308	0.326	10.424	3.3965
30	3.0000	3.4747	1.00	20	41	0.344	20	40	0.352	0.348	10.424	3.6268
33	3.0000	3.3528	1.00	25	46	0.381	20	40	0.352	0.367	10.058	3.6892
36	3.0000	3.3223	1.00	25	46	0.381	20	50	0.285	0.333	9.967	3.3217
39	3.0000	3.2918	1.00	25	46	0.381	25	49	0.359	0.370	9.876	3.6562
42	3.0000	3.3223	1.00	25	40	0.437	25	43	0.407	0.422	9.967	4.2055
45	3.0000	3.3528	1.00	25	42	0.417	20	48	0.297	0.357	10.058	3.5875
48	3.0000	3.2918	1.00	25	40	0.437	20	42	0.336	0.386	9.876	3.8151
51	3.0000	3.0175	1.00	25	41	0.426	25	43	0.407	0.417	9.053	3.7730
54	3.0000	2.5908	1.00	25	43	0.407	20	44	0.321	0.364	7.772	2.8309
57	3.0000	2.6518	1.00	25	48	0.366	20	43	0.328	0.347	7.955	2.7628
60	3.0000	1.8593	1.00	20	44	0.321	20	44	0.321	0.321	5.578	1.7920
63	3.0000	1.4630	1.00	15	40	0.267	15	40	0.267	0.267	4.389	1.1738
66	3.0000	1.1278	1.00	15	49	0.219	15	52	0.207	0.213	3.383	0.7197
69	2.0000	0.3962	0.92	10	41	0.161	10	41	0.161	0.161	0.792	0.1277
70	0.5000	0.0000	1.00	0	0	0.000	0	0	0.000	0.000	0.000	0.0000

DATE:	86-01-22
TIME:	1005-1115
METER NO:	USGS I-39
SUSPENSION:	ROD
A1:	0.7041
B1:	0.0034
BREAK IN REV/S:	0.4255
A2:	0.6773
B2:	0.0134
DATE RATED:	1976-81
RATED AT:	HIF
RATED ON:	ROD
REMARK:	ORIGINAL
NO. OF VERT.:	25.0000
WIDTH (M):	70.0000
MEAN VEL. (M/S)	0.3323
AREA (SQ. M.):	173.1569
DISCHARGE (CMS)	57.5372

TABLE 17. RED RIVER AT EMERSON, MN JANUARY 22, 1986

2ND MEASUREMENT - USGS WITH ICE VANE METER I-39 ON ROD

STATION	WIDTH	DEPTH	COEFF	REV 0.2D	TIM 0.2D	VEL 0.2D	REV 0.8D	TIM 0.8D	VEL 0.8D	MEAN VEL.	AREA	FLOW
0	1.5000	0.0000	1.00	0	0	0.000	0	0	0.000	0.000	0.000	0.0000
3	3.0000	0.8534	1.00	10	44	0.163	10	42	0.171	0.167	2.560	0.4282
6	3.0000	1.5850	1.00	15	49	0.219	15	49	0.219	0.219	4.755	1.0410
9	3.0000	1.7069	1.00	15	40	0.267	15	44	0.243	0.255	5.121	1.3080
12	3.0000	2.1031	1.00	15	40	0.267	15	44	0.243	0.255	6.309	1.6116
15	3.0000	2.4384	1.00	20	49	0.291	15	42	0.255	0.273	7.315	1.9958
18	3.0000	2.6518	1.00	20	45	0.314	20	49	0.291	0.303	7.955	2.4073
21	3.0000	3.0175	1.00	20	41	0.344	20	45	0.314	0.329	9.053	2.9793
24	3.0000	3.3833	1.00	20	41	0.344	20	44	0.321	0.333	10.150	3.3751
27	3.0000	3.4442	1.00	25	47	0.374	20	43	0.328	0.351	10.333	3.6272
30	3.0000	3.4442	1.00	20	41	0.344	20	42	0.336	0.340	10.333	3.5116
33	3.0000	3.3833	1.00	20	40	0.352	20	43	0.328	0.340	10.150	3.4533
36	3.0000	3.3223	1.00	25	43	0.407	20	48	0.297	0.352	9.967	3.5081
39	3.0000	3.2918	1.00	25	43	0.407	25	42	0.417	0.412	9.876	4.0674
42	3.0000	3.3223	1.00	25	40	0.437	20	41	0.344	0.390	9.967	3.8896
45	3.0000	3.3833	1.00	30	46	0.455	25	43	0.407	0.431	10.150	4.3761
48	3.0000	3.3223	1.00	25	42	0.417	20	40	0.352	0.384	9.967	3.8303
51	3.0000	3.0175	1.00	25	41	0.426	20	44	0.321	0.374	9.053	3.3841
54	3.0000	2.5603	1.00	30	47	0.446	25	47	0.374	0.410	7.681	3.1468
57	3.0000	2.6518	1.00	20	40	0.352	20	42	0.336	0.344	7.955	2.7365
60	3.0000	1.7983	1.00	20	45	0.314	20	47	0.302	0.308	5.395	1.6617
63	3.0000	1.4326	1.00	15	42	0.255	20	52	0.274	0.265	4.298	1.1369
66	3.0000	1.1582	1.00	15	51	0.210	15	50	0.215	0.213	3.475	0.7386
69	2.0000	0.3658	0.92	10	46	0.144	10	46	0.144	0.144	0.732	0.1053
70	0.5000	0.0000	1.00	0	0	0.000	0	0	0.000	0.000	0.000	0.0000

DATE:	86-01-22
TIME:	1325-1440
METER NO:	USGS I-39
SUSPENSION:	ROD
A1:	0.7041
B1:	0.0034
BREAK IN REV/S:	0.4255
A2:	0.6773
B2:	0.0134
DATE RATED:	1976-81
RATED AT:	HIF
RATED ON:	ROD
REMARK:	ORIGINAL
NO. OF VERT.:	25.0000
WIDTH (M):	70.0000
MEAN VEL. (M/S)	0.3380
AREA (SQ. M.):	172.5473
DISCHARGE (CMS)	58.3200

TABLE 18. RED RIVER AT EMERSON, MN JANUARY 23, 1986

1ST MEASUREMENT - USGS WITH ICE VANE METER I-39 ON ROD

STATION	WIDTH	DEPTH	COEFF	REV 0.2D	TIM 0.2D	VEL 0.2D	REV 0.8D	TIM 0.8D	VEL 0.8D	MEAN VEL.	AREA	FLOW
0	1.5000	0.0000	1.00	0	0	0.000	0	0	0.000	0.000	0.000	0.0000
3	3.0000	0.8839	1.00	10	46	0.156	10	42	0.171	0.164	2.652	0.4342
6	3.0000	1.6154	1.00	15	46	0.233	15	45	0.238	0.236	4.846	1.1415
9	3.0000	1.7374	1.00	15	41	0.261	15	46	0.233	0.247	5.212	1.2874
12	3.0000	2.1031	1.00	20	52	0.274	15	42	0.255	0.265	6.309	1.6691
15	3.0000	2.4384	1.00	20	47	0.302	20	51	0.280	0.291	7.315	2.1255
18	3.0000	2.6213	1.00	20	43	0.328	20	50	0.285	0.307	7.864	2.4121
21	3.0000	3.0785	1.00	20	42	0.336	20	43	0.328	0.332	9.235	3.0678
24	3.0000	3.3833	1.00	20	40	0.352	20	42	0.336	0.344	10.150	3.4914
27	3.0000	3.4138	1.00	20	41	0.344	20	41	0.344	0.344	10.241	3.5209
30	3.0000	3.4138	1.00	25	47	0.374	20	40	0.352	0.363	10.241	3.7161
33	3.0000	3.3528	1.00	25	46	0.381	20	40	0.352	0.367	10.058	3.6892
36	3.0000	3.2918	1.00	25	44	0.398	20	44	0.321	0.360	9.876	3.5527
39	3.0000	3.2918	1.00	25	43	0.407	25	44	0.398	0.403	9.876	3.9769
42	3.0000	3.3223	1.00	25	40	0.437	25	43	0.407	0.422	9.967	4.2055
45	3.0000	3.3833	1.00	30	46	0.455	25	45	0.390	0.422	10.150	4.2873
48	3.0000	3.2918	1.00	30	47	0.446	25	47	0.374	0.410	9.876	4.0459
51	3.0000	3.0175	1.00	30	47	0.446	25	45	0.390	0.418	9.053	3.7812
54	3.0000	2.5298	1.00	30	50	0.420	25	47	0.374	0.397	7.590	3.0109
57	3.0000	2.6518	1.00	25	47	0.374	20	45	0.314	0.344	7.955	2.7370
60	3.0000	1.8593	1.00	20	42	0.336	15	40	0.267	0.302	5.578	1.6827
63	3.0000	1.4326	1.00	15	40	0.267	15	42	0.255	0.261	4.298	1.1223
66	3.0000	1.1278	1.00	15	49	0.219	15	50	0.215	0.217	3.383	0.7334
69	2.0000	0.3658	0.92	10	47	0.141	10	47	0.141	0.141	0.732	0.1031
70	0.5000	0.0000	1.00	0	0	0.000	0	0	0.000	0.000	0.000	0.0000

DATE:	86-01-23
TIME:	0855-1010
METER NO:	USGS I-39
SUSPENSION:	ROD
A1:	0.7041
B1:	0.0034
BREAK IN REV/S:	0.4255
A2:	0.6773
B2:	0.0134
DATE RATED:	1976-81
RATED AT:	HIF
RATED ON:	ROD
REMARK:	ORIGINAL
NO. OF VERT.:	25.0000
WIDTH (M):	70.0000
MEAN VEL. (M/S)	0.3467
AREA (SQ. M.):	172.4558
DISCHARGE (CMS)	59.7942

TABLE 19. RED RIVER AT EMERSON, MN JANUARY 23, 1986

2ND MEASUREMENT - USGS WITH ICE VANE METER I-39 ON ROD

STATION	WIDTH	DEPTH	COEFF	REV 0.2D	TIM 0.2D	VEL 0.2D	REV 0.8D	TIM 0.8D	VEL 0.8D	MEAN VEL.	AREA	FLOW
0	1.5000	0.0000	1.00	0	0	0.000	0	0	0.000	0.000	0.000	0.0000
3	3.0000	0.8839	1.00	10	46	0.156	10	43	0.167	0.162	2.652	0.4291
6	3.0000	1.6154	1.00	15	45	0.238	15	43	0.249	0.244	4.846	1.1804
9	3.0000	1.7374	1.00	15	43	0.249	15	47	0.228	0.239	5.212	1.2434
12	3.0000	2.1031	1.00	20	49	0.291	15	50	0.215	0.253	6.309	1.5944
15	3.0000	2.4689	1.00	20	51	0.280	15	42	0.255	0.267	7.407	1.9790
18	3.0000	2.6213	1.00	20	45	0.314	20	50	0.285	0.300	7.864	2.3570
21	3.0000	3.1090	1.00	20	41	0.344	20	46	0.308	0.326	9.327	3.0390
24	3.0000	3.3833	1.00	25	48	0.366	20	46	0.308	0.337	10.150	3.4207
27	3.0000	3.4138	1.00	20	41	0.344	20	41	0.344	0.344	10.241	3.5209
30	3.0000	3.4138	1.00	20	40	0.352	25	47	0.374	0.363	10.241	3.7161
33	3.0000	3.3528	1.00	25	45	0.390	25	49	0.359	0.374	10.058	3.7651
36	3.0000	3.3223	1.00	25	45	0.390	20	40	0.352	0.371	9.967	3.6964
39	3.0000	3.2918	1.00	30	47	0.446	25	45	0.390	0.418	9.876	4.1250
42	3.0000	3.3223	1.00	25	40	0.437	25	47	0.374	0.405	9.967	4.0385
45	3.0000	3.3833	1.00	30	46	0.455	25	48	0.366	0.411	10.150	4.1679
48	3.0000	3.2918	1.00	30	45	0.465	25	47	0.374	0.419	9.876	4.1408
51	3.0000	3.0480	1.00	25	42	0.417	20	40	0.352	0.384	9.144	3.5141
54	3.0000	2.5603	1.00	25	45	0.390	25	48	0.366	0.378	7.681	2.9028
57	3.0000	2.6518	1.00	25	46	0.381	20	40	0.352	0.367	7.955	2.9178
60	3.0000	1.8593	1.00	20	45	0.314	20	47	0.302	0.308	5.578	1.7181
63	3.0000	1.4021	1.00	15	40	0.267	15	40	0.267	0.267	4.206	1.1249
66	3.0000	1.1278	1.00	15	54	0.199	15	55	0.195	0.197	3.383	0.6672
69	2.0000	0.3658	0.92	10	44	0.150	10	44	0.150	0.150	0.732	0.1100
70	0.5000	0.0000	1.00	0	0	0.000	0	0	0.000	0.000	0.000	0.0000

DATE:	86-01-23
TIME:	1020-1130
METER NO:	USGS I-39
SUSPENSION:	ROD
A1:	0.7041
B1:	0.0034
BREAK IN REV/S:	0.4255
A2:	0.6773
B2:	0.0134
DATE RATED:	1976-81
RATED AT:	HIF
RATED ON:	ROD
REMARK:	ORIGINAL
NO. OF VERT.:	25.0000
WIDTH (M):	70.0000
MEAN VEL. (M/S)	0.3435
AREA (SQ. M.):	172.8216
DISCHARGE (CMS)	59.3684

APPENDIX C

CALIBRATION DATA FOR CURRENT METERS (WSC and USGS)

Calibration Data for WSC Winter Meter 6-356

Environment Canada National Calibration Service

Meter number 6-356 Calibration date OCTOBER 1,1984 Velocity in Metres/Sec = .6879 X rev/sec + .0114

REV =>	2	5	10	15	20	30	40	50	60	80	100	150	200	250	<= REV
40	0.045	0.095	0.178	0.262	0.345	0.512	0.679	0.846	1.013	1.347	1.681	2.516	3.351	4.186	40
	0.044	0.094	0.176	0.259	0.341	0.506	0.671	0.836	1.001	1.331	1.661	2.485	3.310	4.134	
41	0.044	0.093	0.174	0.256	0.337	0.500	0.663	0.826	0.989	1.315	1.640	2.455	3.269	4.084	41
	0.044	0.092	0.172	0.253	0.333	0.494	0.655	0.816	0.977	1.299	1.621	2.425	3.230	4.035	
42	0.043	0.091	0.170	0.250	0.329	0.488	0.647	0.807	0.968	1.284	1.602	2.397	3.192	3.987	42
	0.043	0.090	0.169	0.247	0.326	0.483	0.640	0.797	0.954	1.269	1.583	2.369	3.154	3.940	
43	0.042	0.089	0.167	0.244	0.322	0.477	0.633	0.788	0.943	1.254	1.565	2.341	3.118	3.895	43
	0.042	0.088	0.165	0.242	0.318	0.472	0.626	0.779	0.933	1.240	1.547	2.315	3.082	3.850	
44	0.042	0.087	0.163	0.239	0.315	0.467	0.619	0.770	0.922	1.226	1.529	2.288	3.047	3.806	44
SEC	0.041	0.086	0.161	0.237	0.312	0.462	0.612	0.762	0.912	1.212	1.512	2.263	3.013	3.764	SEC
45	0.041	0.086	0.160	0.234	0.308	0.457	0.605	0.754	0.902	1.199	1.496	2.238	2.980	3.722	45
	0.041	0.085	0.158	0.232	0.305	0.452	0.599	0.745	0.892	1.186	1.479	2.213	2.947	3.681	
46	0.040	0.084	0.157	0.229	0.302	0.447	0.592	0.737	0.883	1.173	1.463	2.189	2.915	3.641	46
	0.040	0.083	0.155	0.227	0.299	0.442	0.586	0.730	0.873	1.160	1.448	2.166	2.884	3.602	
47	0.040	0.082	0.154	0.225	0.296	0.438	0.580	0.722	0.864	1.148	1.432	2.143	2.854	3.564	47
	0.040	0.082	0.152	0.222	0.293	0.433	0.574	0.714	0.855	1.136	1.418	2.121	2.824	3.527	
48	0.039	0.081	0.151	0.220	0.290	0.429	0.568	0.707	0.846	1.125	1.403	2.099	2.794	3.490	48
	0.039	0.080	0.149	0.218	0.287	0.425	0.562	0.700	0.838	1.113	1.389	2.077	2.766	3.454	
49	0.039	0.080	0.148	0.216	0.284	0.420	0.557	0.693	0.829	1.102	1.374	2.056	2.738	3.419	49
SEC	0.038	0.079	0.146	0.214	0.281	0.416	0.551	0.686	0.821	1.091	1.361	2.035	2.710	3.385	SEC
50	0.038	0.078	0.145	0.212	0.279	0.412	0.546	0.679	0.813	1.080	1.347	2.015	2.683	3.351	50
	0.038	0.078	0.144	0.210	0.278	0.408	0.540	0.673	0.805	1.069	1.334	1.995	2.657	3.318	
51	0.038	0.077	0.142	0.208	0.273	0.404	0.535	0.668	0.797	1.059	1.321	1.978	2.631	3.285	51
	0.037	0.076	0.141	0.206	0.271	0.400	0.530	0.660	0.790	1.049	1.308	1.957	2.605	3.254	
52	0.037	0.076	0.140	0.204	0.268	0.397	0.525	0.654	0.782	1.039	1.296	1.938	2.580	3.222	52
	0.037	0.075	0.139	0.202	0.266	0.393	0.520	0.647	0.775	1.029	1.284	1.920	2.556	3.192	
53	0.037	0.074	0.137	0.200	0.263	0.389	0.515	0.641	0.768	1.020	1.272	1.902	2.532	3.162	53
	0.036	0.074	0.136	0.199	0.261	0.386	0.511	0.636	0.760	1.010	1.260	1.884	2.508	3.132	
54	0.036	0.073	0.135	0.197	0.259	0.382	0.508	0.630	0.754	1.001	1.248	1.867	2.485	3.104	54
	0.036	0.073	0.134	0.195	0.257	0.379	0.502	0.624	0.747	0.992	1.237	1.850	2.462	3.075	
55	0.038	0.072	0.133	0.194	0.254	0.378	0.497	0.619	0.740	0.983	1.228	1.833	2.440	3.047	55
	0.035	0.072	0.132	0.192	0.252	0.372	0.493	0.613	0.733	0.974	1.215	1.817	2.418	3.020	
56	0.035	0.071	0.131	0.190	0.250	0.369	0.488	0.608	0.727	0.966	1.204	1.800	2.397	2.993	56
	0.035	0.071	0.130	0.189	0.248	0.366	0.484	0.602	0.721	0.957	1.194	1.785	2.376	2.967	
57	0.035	0.070	0.129	0.187	0.246	0.363	0.480	0.597	0.714	0.949	1.183	1.769	2.355	2.941	57
	0.035	0.069	0.128	0.186	0.244	0.360	0.476	0.592	0.708	0.941	1.173	1.754	2.335	2.915	
58	0.034	0.069	0.127	0.184	0.242	0.357	0.472	0.587	0.702	0.933	1.163	1.739	2.315	2.890	58
	0.034	0.068	0.126	0.183	0.240	0.354	0.468	0.582	0.696	0.925	1.153	1.724	2.295	2.866	
59	0.034	0.068	0.125	0.181	0.238	0.351	0.464	0.577	0.691	0.917	1.143	1.709	2.275	2.841	59
SEC	0.034	0.068	0.124	0.180	0.236	0.348	0.460	0.573	0.685	0.909	1.134	1.695	2.256	2.818	SEC
60	0.034	0.067	0.123	0.178	0.234	0.345	0.457	0.568	0.679	0.902	1.125	1.681	2.238	2.784	60
	0.033	0.067	0.122	0.177	0.232	0.343	0.453	0.563	0.674	0.895	1.115	1.667	2.219	2.771	
61	0.033	0.066	0.121	0.176	0.230	0.340	0.449	0.559	0.668	0.887	1.106	1.654	2.201	2.749	61
	0.033	0.066	0.120	0.174	0.229	0.337	0.446	0.554	0.663	0.880	1.097	1.640	2.183	2.726	
62	0.033	0.065	0.119	0.173	0.227	0.335	0.442	0.550	0.658	0.873	1.089	1.627	2.166	2.705	62
	0.033	0.065	0.118	0.172	0.225	0.332	0.439	0.546	0.653	0.866	1.080	1.614	2.149	2.683	
63	0.033	0.064	0.117	0.170	0.223	0.329	0.435	0.541	0.647	0.860	1.072	1.602	2.132	2.662	63
	0.032	0.064	0.117	0.169	0.222	0.327	0.432	0.537	0.642	0.853	1.063	1.589	2.115	2.641	
64	0.032	0.064	0.116	0.168	0.220	0.324	0.429	0.533	0.638	0.846	1.055	1.577	2.099	2.620	64
SEC	0.032	0.063	0.115	0.167	0.219	0.322	0.426	0.529	0.633	0.840	1.047	1.565	2.082	2.600	SEC
65	0.032	0.063	0.114	0.166	0.217	0.320	0.422	0.525	0.628	0.833	1.039	1.553	2.066	2.580	65
	0.032	0.062	0.113	0.164	0.215	0.317	0.419	0.521	0.623	0.827	1.031	1.541	2.051	2.561	
66	0.032	0.062	0.113	0.163	0.214	0.315	0.416	0.517	0.618	0.821	1.023	1.529	2.035	2.541	66
	0.031	0.062	0.112	0.162	0.212	0.313	0.413	0.514	0.614	0.815	1.016	1.518	2.020	2.522	
67	0.031	0.061	0.111	0.161	0.211	0.310	0.410	0.510	0.610	0.809	1.008	1.507	2.005	2.504	67
	0.031	0.061	0.110	0.160	0.209	0.308	0.407	0.506	0.605	0.803	1.001	1.496	1.990	2.485	
68	0.031	0.061	0.110	0.159	0.208	0.306	0.404	0.503	0.601	0.797	0.994	1.485	1.976	2.467	68
	0.031	0.060	0.109	0.158	0.206	0.304	0.401	0.499	0.596	0.791	0.986	1.474	1.961	2.449	
69	0.031	0.060	0.108	0.157	0.205	0.302	0.399	0.495	0.592	0.786	0.979	1.463	1.947	2.431	69
	0.031	0.059	0.108	0.156	0.204	0.300	0.396	0.492	0.588	0.780	0.972	1.453	1.933	2.414	
70	0.030	0.059	0.107	0.155	0.202	0.298	0.393	0.488	0.584	0.775	0.966	1.443	1.920	2.397	70
REV =>	2	5	10	15	20	30	40	50	60	80	100	150	200	250	<= REV

Type of meter PRICE WSC WINTER
Owner WATER SURVEY

Condition at rating REPAIRED
Suspension ROD

CALIBRATION DATA FOR METER # 6-356 -ROD SUSPENDED

RUN NO:	VELOCITY (CM/SEC)	REV/SEC	REV/METRE	EQUATIONS
1	2.01	0.0179	0.8893	
2	4.01	0.0566	1.4124	
3	8.10	0.1134	1.4004	
4	9.07	0.1283	1.4150	
5	10.09	0.1389	1.3761	V=0.6736N + 0.0101 M/S
6	12.06	0.1648	1.3663	
7	14.08	0.1954	1.3880	2.2100N + 0.0330 FT/SEC
8	16.01	0.2238	1.3978	
9	18.08	0.2565	1.4189	
10	20.08	0.2837	1.4128	STANDARD ESTIMATE OF ERROR:
11	25.02	0.3588	1.4341	
12	30.17	0.4300	1.4253	0.005 M/S
13	35.14	0.5005	1.4243	
14	40.10	0.5718	1.4258	0.015 FT/SEC
15	45.14	0.6480	1.4355	
16	50.00	0.7170	1.4339	
17	55.12	0.8050	1.4604	
18	59.99	0.8724	1.4543	
19	70.89	1.0313	1.4548	
20	80.98	1.1839	1.4620	
21	90.99	1.3242	1.4553	
22	100.81	1.4746	1.4627	
23	120.31	1.7668	1.4685	
24	135.82	2.0012	1.4734	
25	151.16	2.2366	1.4796	
26	165.37	2.4462	1.4792	
27	180.89	2.6660	1.4738	
28	195.21	2.8960	1.4835	
29	210.37	3.1172	1.4818	
30	230.62	3.4106	1.4789	
31	250.23	3.6914	1.4752	

COMPOSITE RATING:	EQUATIONS:	STANDARD ESTIMATE OF ERROR:
N < 0.564	V=0.6916N + 0.0043 M/S	0.002 M/S
	2.2690N + 0.0140 FT/SEC	0.007 FT/SEC
0.564 ≤ N	V=0.6712N + 0.0158 M/S	0.004 M/S
	2.2020N + 0.0520 FT/SEC	0.014 FT/SEC

Where V= velocity
N= rev/sec
February,1986

FLUCTUATING VELOCITIES

CALIBRATION DATA FOR METER # 6-356

SUSPENSION:ROD

RUN NO:	AVERAGE VELOCITY (CM/SEC)	REV/SEC	REV/METRE	EQUATIONS
1	18.36	0.2729	1.4865	
2	20.15	0.2805	1.3922	
3	24.28	0.3459	1.4247	
4	26.18	0.3622	1.3835	
5	27.99	0.4072	1.4549	V=0.5520N + 0.0467M/S
6	30.12	0.4989	1.6564	1.8111N + 0.1531FT/SEC
7	31.99	0.5110	1.5975	
8	36.11	0.5430	1.5039	STANDARD ESTIMATE OF ERROR:
				0.014 M/S
				0.047 FT/SEC

Where V= Velocity
N= Rev/Sec
February,1986

CAN ICE CURRENT METER NO. 6-356
DATE RATED: 03-18-86
CONDITIONS: ASRECD
SUSPENSION: ICE ROD
MINIMUM VELOCITY: 0.099
MAXIMUM VELOCITY: 8.002
EQUATION COEFFICIENTS: M1= 2.246 A1= 0.016
STANDARD ERROR: 0.0110191
CORR. COEFFICIENT: 0.999989

RUN	DISTANCE	TIME	COUNTS	V,FT/SEC	R,REV/SEC	* LOW	EFF,REV/FT	HIGH *	CV,COMP.VEL.	CD,CALC.DIFF.
1	26.78	269.89	10.0	0.100	0.037	*0.836	0.373	0.943	0.100	0.000
2	28.26	284.34	10.0	0.099	0.035	*0.836	0.354	0.943	0.095	-0.004
3	25.97	162.99	10.0	0.159	0.061	*0.932	0.385	0.997	0.154	-0.006
4	25.99	162.66	10.0	0.160	0.061	*0.932	0.385	0.997	0.154	-0.006
5	24.57	95.73	10.0	0.257	0.104	*0.965	0.407	1.014	0.251	-0.006
6	24.49	95.31	10.0	0.257	0.105	*0.965	0.408	1.014	0.252	-0.005
7	46.63	93.23	20.0	0.500	0.215	*0.996	0.429	1.033	0.498	-0.002
8	46.65	93.40	20.0	0.499	0.214	*0.996	0.429	1.033	0.497	-0.002
9	46.24	60.41	20.0	0.765	0.331	*1.007	0.433	1.038	0.760	-0.006
10	46.15	61.05	20.0	0.756	0.328	*1.007	0.433	1.038	0.752	-0.004
11	91.23	60.86	40.0	1.499	0.657	*1.012	0.438	1.042	1.492	-0.007
12	91.05	61.23	40.0	1.487	0.653	*1.012	0.439	1.042	1.483	-0.004
13	89.86	40.52	40.0	2.218	0.987	0.000	0.445	0.836	2.233	0.016
14	90.04	40.77	40.0	2.208	0.981	0.000	0.444	0.836	2.220	0.011
15	89.60	30.00	40.0	2.987	1.333	0.000	0.446	0.932	3.011	0.024
16	90.18	30.18	40.0	2.988	1.325	0.000	0.444	0.932	2.993	0.005
17	89.69	17.94	40.0	4.999	2.230	0.000	0.446	0.965	5.024	0.025
18	90.11	18.02	40.0	5.001	2.220	0.000	0.444	0.965	5.002	0.002
19	90.16	11.28	40.0	7.993	3.546	0.000	0.444	0.996	7.981	-0.011
20	90.26	11.28	40.0	8.002	3.546	0.000	0.443	0.996	7.981	-0.020

TOTAL DIFFERENCE= 0.000

CAN ICE CURRENT METER NO. 6-356
DATE RATED: 03-18-86
CONDITIONS: ASRECD
SUSPENSION: ICE ROD
MINIMUM VELOCITY: 0.099
MAXIMUM VELOCITY: 8.002
EQUATION COEFFICIENTS: M1= 2.231 A1= 0.023
M2= 2.268 A2= -0.046
R, REV/SEC AT BREAKPOINT: 1.833
VEL,FT/SEC AT BREAKPOINT: 4.112
STANDARD ERROR: 0.0062407

RUN	DISTANCE	TIME	COUNTS	V,FT/SEC	R,REV/SEC	* LOW	EFF,REV/FT	HIGH *	CV,COMP.VEL.	CD,CALC.DIFF
1	26.78	269.89	10.0	0.100	0.037		0.373		0.106	-0.006
2	28.26	284.34	10.0	0.099	0.035		0.354		0.101	-0.002
3	25.97	162.99	10.0	0.159	0.061		0.385		0.160	-0.001
4	25.99	162.66	10.0	0.160	0.061		0.385		0.160	0.000
5	24.57	95.73	10.0	0.257	0.104		0.407		0.256	0.001
6	24.49	95.31	10.0	0.257	0.105		0.408		0.257	0.000
7	46.63	93.23	20.0	0.500	0.215		0.429		0.502	-0.001
8	46.65	93.40	20.0	0.499	0.214		0.429		0.501	-0.001
9	46.24	60.41	20.0	0.765	0.331		0.433		0.761	0.004
10	46.15	61.05	20.0	0.756	0.328		0.433		0.754	0.002
11	91.23	60.86	40.0	1.499	0.657		0.438		1.489	0.010
12	91.05	61.23	40.0	1.487	0.653		0.439		1.480	0.007
13	89.86	40.52	40.0	2.218	0.987		0.445		2.225	-0.007
14	90.04	40.77	40.0	2.208	0.981		0.444		2.211	-0.003
15	89.60	30.00	40.0	2.987	1.333		0.446		2.997	-0.010
16	90.18	30.18	40.0	2.988	1.325		0.444		2.979	0.009
17	89.69	17.94	40.0	4.999	2.230		0.446		5.011	-0.012
18	90.11	18.02	40.0	5.001	2.220		0.444		4.989	0.012
19	90.16	11.28	40.0	7.993	3.546		0.444		7.997	-0.004
20	90.26	11.28	40.0	8.002	3.546		0.443		7.997	0.004

TOTAL DIFFERENCE= 0.000

3 PTS. IN LOWER LINE; 7 PTS. IN UPPER LINE	M1= 2.290	A1= 0.018	M2= 2.248	A2= 0.011	STANDARD ERROR= 0.0115362
4 PTS. IN LOWER LINE; 6 PTS. IN UPPER LINE	M1= 2.239	A1= 0.021	M2= 2.249	A2= 0.009	STANDARD ERROR= 0.0093797
5 PTS. IN LOWER LINE; 5 PTS. IN UPPER LINE	M1= 2.247	A1= 0.020	M2= 2.252	A2= 0.001	STANDARD ERROR= 0.0120136
6 PTS. IN LOWER LINE; 4 PTS. IN UPPER LINE	M1= 2.248	A1= 0.020	M2= 2.258	A2=-0.014	STANDARD ERROR= 0.0123910
7 PTS. IN LOWER LINE; 3 PTS. IN UPPER LINE	M1= 2.232	A1= 0.023	M2= 2.261	A2=-0.022	STANDARD ERROR= 0.0067190
8 PTS. IN LOWER LINE; 2 PTS. IN UPPER LINE	M1= 2.231	A1= 0.023	M2= 2.268	A2=-0.046	STANDARD ERROR= 0.0062407
10 PTS. IN LOWER LINE; 0 PTS. IN UPPER LINE	M1= 2.246	A1= 0.016	M2= 0.000	A2= 0.000	STANDARD ERROR= 0.0110191

CALIBRATION DATA FOR CURRENT METER # 6-356, FIELD ROD SUSPENSION

SEPTEMBER 18,1986

RUN NO.:	VELOCITY (CM/SEC)	TIME (SEC)	REVS	REVS/SEC	REV/METRE
1	10.09	127.35	18	0.1491951	1.4786435
2	14.97	88.07	19	0.2133154	1.4249524
3	20.05	66.31	19	0.2865330	1.4290920
4	25.09	54.09	20	0.3697541	1.4737111
5	30.01	45.05	20	0.4439512	1.4793441
6	35.09	77.35	40	0.5171289	1.4737245
7	40.19	67.06	40	0.5964806	1.4841522
8	45.14	60.07	40	0.6658888	1.4751557
9	50.14	53.82	40	0.7432181	1.4822859
10	55.14	48.20	40	0.8130081	1.4744435
11	60.12	45.07	40	0.8875083	1.4762281
12	70.74	57.37	60	1.0458428	1.4784320
13	80.43	50.50	60	1.1881186	1.4772085
14	90.54	44.67	60	1.3431833	1.4835248
15	100.38	40.23	60	1.4914243	1.4857784
16	120.01	56.05	100	1.7841213	1.4866439
17	149.61	44 93	100	2.2256844	1.4876575
18	181.05	37.16	100	2.6910657	1.4863660
19	210.58	32.00	100	3.1250000	1.4839966
20	250.33	26.80	100	3.7313433	1.4905688

EQUATION: STANDARD ESTIMATE OF ERROR:

V= 0.6708N + 0 0044 M/S 0.0025 M/S

2.2008N + 0.0144 FT/SEC 0.0082 FT/SEC

LOW SPEED CALIBRATION DATA CURRENT METER # 6-356, FIELD ROD SUSPENSION

SEPTEMBER 18,1986

RUN NO.:	VELOCITY (CM/SEC)	TIME (SEC)	REVS	REVS/SEC	REV/METRE
1	3.52	204.50	5	0.0244499	0.6945888
2	5.05	103.60	6	0.0579151	1.1468328
3	6.00	68.93	5	0.0725374	1.2089559
4	8.02	96.21	10	0.1038393	1.2950012
5	10.02	72.56	10	0.1378170	1.3754180
6	12.01	57.78	10	0.1731302	1.4415503
7	14.12	99.18	20	0.2016535	1.4281414
8	16.09	85.03	20	0.2352111	1.4618465
9	18.12	76.34	20	0.2618859	1.4458380
10	20.24	69.08	20	0.2895184	1.4304318
11	22.15	61.35	20	0.3259984	1.4717759
12	24.09	56.82	20	0.3519887	1.4611405
13	26.06	51.73	20	0.3866225	1.4824496
14	28.13	48.02	20	0.4164831	1.4806012
15	30.23	44.82	20	0.4462294	1.4761143
16	32.36	84.24	40	0.4748338	1.4673480
17	34.13	80.12	40	0.4992511	1.4627826
18	36.11	75.53	40	0.5295909	1.4666045
19	38.15	71.77	40	0.5573359	1.4609068
20	40.19	67.83	40	0.5897096	1.4673042
21	42.25	64.52	40	0.6199626	1.4673676
22	44.26	61.48	40	0.6506181	1.4699812
23	46.27	58.85	40	0.6796941	1.4689737
24	48.13	56.54	40	0.7074637	1.4699018
25	50.21	54.13	40	0.7389516	1.4717422
26	52.13	52.15	40	0.7670182	1.4713566
27	54.16	50.44	40	0.7930214	1.4642197
28	56.23	48.50	40	0.8247423	1.4667300
29	58.07	47.02	40	0.8507016	1.4649582
30	60.15	45.28	40	0.8833922	1.4686488

EQUATION: STANDARD ESTIMATE OF ERROR:

V= 0.6690N + 0.0078 M/S 0.0035 M/S

2.1948N + 0.0256 FT/SEC 0.0115 FT/SEC

COMPOSITE RATING EQUATIONS: STANDARD ESTIMATE OF ERROR:

N < 0.210 V= 0.6014N + 0.0178 M/S 0.0021 M/S

1.9731N + 0.0577 FT/SEC 0.0069 FT/SEC

0.210 ≤ N V= 0.6794N + 0.0012 M/S 0.0017 M/S

2.2290N + 0.0039 FT/SEC 0.0056 FT/SEC

Calibration Data for WSC Winter Meter 6-288

Environment Canada National Calibration Service

Meter number 6-288 Calibration date AUGUST 23,1984 Velocity in Metres/Sec = .684 X rev/sec + 0

REV =>	2	5	10	15	20	30	40	50	60	80	100	150	200	250	<= REV
40	0.034	0.086	0.171	0.257	0.342	0.513	0.684	0.855	1.026	1.368	1.710	2.565	3.420	4.275	40
	0.034	0.084	0.169	0.253	0.338	0.507	0.676	0.844	1.013	1.351	1.689	2.533	3.378	4.222	
41	0.033	0.083	0.167	0.250	0.334	0.500	0.667	0.834	1.001	1.335	1.668	2.502	3.337	4.171	41
	0.033	0.082	0.165	0.247	0.330	0.494	0.659	0.824	0.989	1.319	1.648	2.472	3.296	4.120	
42	0.033	0.081	0.163	0.244	0.326	0.489	0.651	0.814	0.977	1.303	1.629	2.443	3.257	4.071	42
	0.032	0.080	0.161	0.241	0.322	0.483	0.644	0.805	0.966	1.288	1.609	2.414	3.219	4.024	
43	0.032	0.080	0.159	0.239	0.318	0.477	0.636	0.795	0.954	1.273	1.591	2.386	3.181	3.977	43
	0.031	0.079	0.157	0.238	0.314	0.472	0.629	0.786	0.943	1.258	1.572	2.359	3.145	3.931	
44	0.031	0.078	0.155	0.233	0.311	0.466	0.622	0.777	0.933	1.244	1.555	2.332	3.109	3.886	44
SEC	0.031	0.077	0.154	0.231	0.307	0.461	0.615	0.769	0.922	1.230	1.537	2.306	3.074	3.843	SEC
45	0.030	0.076	0.152	0.228	0.304	0.456	0.608	0.760	0.912	1.216	1.520	2.280	3.040	3.800	45
	0.030	0.075	0.150	0.225	0.301	0.451	0.601	0.752	0.902	1.203	1.503	2.255	3.007	3.758	
46	0.030	0.074	0.149	0.223	0.297	0.446	0.595	0.743	0.892	1.190	1.487	2.230	2.974	3.717	46
	0.029	0.074	0.147	0.221	0.294	0.441	0.588	0.735	0.883	1.177	1.471	2.206	2.942	3.677	
47	0.029	0.073	0.146	0.218	0.291	0.437	0.582	0.728	0.873	1.164	1.455	2.183	2.911	3.638	47
	0.029	0.072	0.144	0.216	0.288	0.432	0.576	0.720	0.864	1.152	1.440	2.160	2.880	3.600	
48	0.029	0.071	0.143	0.214	0.285	0.428	0.570	0.713	0.855	1.140	1.425	2.138	2.850	3.563	48
	0.028	0.071	0.141	0.212	0.282	0.423	0.564	0.705	0.846	1.128	1.410	2.115	2.821	3.526	
49	0.028	0.070	0.140	0.209	0.279	0.419	0.558	0.698	0.838	1.117	1.396	2.094	2.792	3.490	49
SEC	0.028	0.069	0.138	0.207	0.276	0.415	0.553	0.691	0.829	1.105	1.382	2.073	2.764	3.455	SEC
50	0.027	0.068	0.137	0.205	0.274	0.410	0.547	0.684	0.821	1.094	1.368	2.052	2.736	3.420	50
	0.027	0.068	0.135	0.203	0.271	0.406	0.542	0.677	0.813	1.084	1.354	2.032	2.709	3.385	
51	0.027	0.067	0.134	0.201	0.268	0.402	0.536	0.671	0.805	1.073	1.341	2.012	2.682	3.353	51
	0.027	0.066	0.133	0.199	0.266	0.398	0.531	0.664	0.797	1.063	1.328	1.992	2.656	3.320	
52	0.026	0.066	0.132	0.197	0.263	0.395	0.526	0.658	0.789	1.052	1.315	1.973	2.631	3.288	52
	0.026	0.065	0.130	0.195	0.261	0.391	0.521	0.651	0.782	1.042	1.303	1.954	2.606	3.257	
53	0.026	0.065	0.129	0.194	0.258	0.387	0.516	0.645	0.774	1.032	1.291	1.936	2.581	3.226	53
	0.026	0.064	0.128	0.192	0.256	0.384	0.511	0.639	0.767	1.023	1.279	1.918	2.557	3.196	
54	0.025	0.063	0.127	0.190	0.253	0.380	0.507	0.633	0.760	1.013	1.267	1.900	2.533	3.167	54
	0.025	0.063	0.126	0.188	0.251	0.377	0.502	0.628	0.753	1.004	1.255	1.883	2.510	3.138	
55	0.025	0.062	0.124	0.187	0.249	0.373	0.497	0.622	0.746	0.995	1.244	1.865	2.487	3.109	55
	0.025	0.062	0.123	0.185	0.246	0.370	0.493	0.616	0.739	0.986	1.232	1.849	2.465	3.081	
56	0.024	0.061	0.122	0.183	0.244	0.366	0.489	0.611	0.733	0.977	1.221	1.832	2.443	3.054	56
	0.024	0.061	0.121	0.182	0.242	0.363	0.484	0.605	0.726	0.968	1.211	1.816	2.421	3.027	
57	0.024	0.060	0.120	0.180	0.240	0.360	0.480	0.600	0.720	0.960	1.200	1.800	2.400	3.000	57
	0.024	0.059	0.119	0.178	0.238	0.357	0.476	0.595	0.714	0.952	1.190	1.784	2.379	2.974	
58	0.024	0.059	0.118	0.177	0.236	0.354	0.472	0.590	0.708	0.943	1.179	1.769	2.359	2.948	58
	0.023	0.058	0.117	0.175	0.234	0.351	0.468	0.585	0.702	0.935	1.169	1.754	2.338	2.923	
59	0.023	0.058	0.116	0.174	0.232	0.348	0.464	0.580	0.696	0.927	1.159	1.739	2.319	2.898	59
SEC	0.023	0.057	0.115	0.172	0.230	0.345	0.460	0.575	0.690	0.920	1.150	1.724	2.299	2.874	SEC
60	0.023	0.057	0.114	0.171	0.228	0.342	0.456	0.570	0.684	0.912	1.140	1.710	2.280	2.850	60
	0.023	0.057	0.113	0.170	0.226	0.339	0.452	0.565	0.678	0.904	1.131	1.696	2.261	2.826	
61	0.022	0.056	0.112	0.168	0.224	0.336	0.449	0.561	0.673	0.897	1.121	1.682	2.243	2.803	61
	0.022	0.056	0.111	0.167	0.222	0.334	0.445	0.556	0.667	0.890	1.112	1.668	2.224	2.780	
62	0.022	0.055	0.110	0.165	0.221	0.331	0.441	0.552	0.662	0.883	1.103	1.655	2.206	2.758	62
	0.022	0.055	0.109	0.164	0.219	0.328	0.438	0.547	0.657	0.876	1.094	1.642	2.189	2.736	
63	0.022	0.054	0.109	0.163	0.217	0.326	0.434	0.543	0.651	0.869	1.086	1.629	2.171	2.714	63
	0.022	0.054	0.108	0.162	0.215	0.323	0.431	0.539	0.646	0.862	1.077	1.616	2.154	2.693	
64	0.021	0.053	0.107	0.160	0.214	0.321	0.428	0.534	0.641	0.855	1.069	1.603	2.138	2.672	64
SEC	0.021	0.053	0.106	0.159	0.212	0.318	0.424	0.530	0.636	0.848	1.060	1.591	2.121	2.651	SEC
65	0.021	0.053	0.105	0.158	0.210	0.316	0.421	0.526	0.631	0.842	1.052	1.578	2.105	2.631	65
	0.021	0.052	0.104	0.157	0.209	0.313	0.418	0.522	0.627	0.835	1.044	1.566	2.089	2.611	
66	0.021	0.052	0.104	0.155	0.207	0.311	0.415	0.518	0.622	0.829	1.036	1.555	2.073	2.591	66
	0.021	0.051	0.103	0.154	0.206	0.309	0.411	0.514	0.617	0.823	1.029	1.543	2.057	2.571	
67	0.020	0.051	0.102	0.153	0.204	0.306	0.408	0.510	0.613	0.817	1.021	1.531	2.042	2.552	67
	0.020	0.051	0.101	0.152	0.203	0.304	0.405	0.507	0.608	0.811	1.013	1.520	2.027	2.533	
68	0.020	0.050	0.101	0.151	0.201	0.302	0.402	0.503	0.604	0.805	1.006	1.509	2.012	2.515	68
	0.020	0.050	0.100	0.150	0.200	0.300	0.399	0.499	0.599	0.799	0.999	1.498	1.997	2.496	
69	0.020	0.050	0.099	0.149	0.198	0.297	0.397	0.496	0.595	0.793	0.991	1.487	1.983	2.478	69
	0.020	0.049	0.098	0.148	0.197	0.295	0.394	0.492	0.591	0.787	0.984	1.476	1.968	2.460	
70	0.020	0.049	0.098	0.147	0.195	0.293	0.391	0.489	0.586	0.782	0.977	1.466	1.954	2.443	70
REV =>	2	5	10	15	20	30	40	50	60	80	100	150	200	250	<= REV

Type of meter WSC WINTER
Owner WATER SURVEY

Condition at rating REPAIRED
Suspension ROD

CALIBRATION DATA FOR METER # 6-288 -ROD SUSPENDED

RUN NO:	VELOCITY (CM/SEC)	REV/SEC	REV/METRE	EQUATIONS
1	2.01	0.0171	0.8514	
2	4.01	0.0559	1.3932	
3	8.12	0.1185	1.4592	
4	9.07	0.1285	1.4171	
5	10.09	0.1370	1.3576	V=0.6775N + 0.0082 M/S
6	12.06	0.1637	1.3571	
7	14.08	0.1976	1.4036	2.2229N + 0.0268 FT/SEC
8	16.01	0.2250	1.4052	
9	18.08	0.2574	1.4237	
10	20.08	0.2818	1.4032	STANDARD ESTIMATE OF ERROR:
11	25.02	0.3604	1.4403	
12	30.17	0.4314	1.4299	0.003 M/S
13	35.14	0.5014	1.4270	
14	40.10	0.5768	1.4384	0.010 FT/SEC
15	45.14	0.6523	1.4451	
16	50.00	0.7205	1.4409	
17	55.12	0.8037	1.4581	
18	59.99	0.8698	1.4498	
19	70.89	1.0295	1.4523	
20	80.98	1.1755	1.4517	
21	90.99	1.3251	1.4563	
22	100.81	1.4720	1.4602	
23	120.31	1.7634	1.4657	
24	135.82	1.9920	1.4667	
25	151.16	2.2202	1.4688	
26	165.37	2.4313	1.4702	
27	180.89	2.6525	1.4664	
28	195.21	2.8752	1.4729	
29	210.37	3.1008	1.4740	
30	230.62	3.3921	1.4709	
31	250.23	3.6805	1.4709	

COMPOSITE RATING:	EQUATIONS:	STANDARD ESTIMATE OF ERROR:
N < 0.965	V=0.6840N + 0.0054 M/S	0.003 M/S
	2.2440N + 0.0179 FT/SEC	0.009 FT/SEC
0.965 ≤ N	V=0.6752N + 0.0139 M/S	0.003 M/S
	2.2153N + 0.0455 FT/SEC	0.008 FT/SEC

Where V= velocity
N= rev/sec
February,1986

CALIBRATION DATA FOR METER # 6-288
SUSPENSION:WINTER WEIGHT ASSEMBLY:

RUN NO:	VELOCITY (CM/SEC)	REV/SEC	REV/METRE	EQUATIONS
1	3.01	0.0271	0.8987	
2	5.02	0.0587	1.1695	
3	7.12	0.0773	1.0859	
4	10.13	0.1155	1.1399	
5	12.01	0.1439	1.1980	V=0.7001N + 0.0145 M/S
6	14.05	0.1698	1.2084	
7	16.04	0.2000	1.2469	2.2968N + 0.0475 FT/SEC
8	18.04	0.2288	1.2685	
9	20.08	0.2526	1.2579	
10	25.02	0.3254	1.3004	STANDARD ESTIMATE OF ERROR:
11	30.15	0.4004	1.3280	
12	35.13	0.4859	1.3832	0.014 M/S
13	40.05	0.5557	1.3875	
14	45.15	0.6284	1.3919	0.045 FT/SEC
15	50.06	0.6922	1.3827	
16	55.04	0.7673	1.3941	
17	60.04	0.8340	1.3891	
18	70.80	0.9841	1.3900	
19	80.98	1.1342	1.4006	
20	90.67	1.2799	1.4116	
21	100.77	1.4310	1.4200	
22	120.94	1.7235	1.4251	
23	135.80	1.9508	1.4366	
24	151.16	2.1664	1.4332	
25	165.69	2.3742	1.4329	
26	180.71	2.5880	1.4321	
27	194.97	2.7832	1.4275	
28	210.81	2.9886	1.4177	
29	230.67	3.2436	1.4062	
30	250.46	3.4892	1.3931	

COMPOSITE RATING:	EQUATIONS:	STANDARD ESTIMATE OF ERROR:
N < 0.156	V=0.7926N + 0.0076 M/S	0.003 M/S
	2.6003N + 0.0250 FT/SEC	0.010 FT/SEC
0.156 ≤ N ≤ 2.683	V=0.6878N + 0.0239 M/S	0.004 M/S
	2.2565N + 0.0783 FT/SEC	0.013 FT/SEC
2.683 ≤ N	V=0.7855N - 0.2382 M/S	0.003 M/S
	2.5770N - 0.7815 FT/SEC	0.010 FT/SEC

Where V= velocity
N= rev/sec
February,1986

FLUCTUATING VELOCITIES

CALIBRATION DATA FOR METER # 6-288

SUSPENSION:WINTER WEIGHT ASSEMBLY

RUN NO:	AVERAGE VELOCITY (CM/SEC)	REV/SEC	REV/METRE	EQUATIONS
1	18.36	0.2414	1.3151	
2	20.15	0.2488	1.2345	
3	22.12	0.2821	1.2755	
4	24.28	0.3181	1.3100	
5	26.18	0.3586	1.3697	V=0.6441N + 0.0357M/S
6	27.99	0.3826	1.3668	2.1131N + 0.1173FT/SEC
7	30.12	0.4044	1.3425	
8	31.99	0.4444	1.3893	STANDARD ESTIMATE OF ERROR:
9	34.52	0.4862	1.4085	0.005 M/S
10	36.11	0.4989	1.3817	0.016 FT/SEC

Where V= Velocity
n= Rev/sec
February,1986

CAN ICE CURRENT METER NO. 6-288
DATE RATED: 03-18-86
CONDITIONS: ASRECD
SUSPENSION: ICE ROD
MINIMUM VELOCITY: 0.099
MAXIMUM VELOCITY: 8.005
EQUATION COEFFICIENTS: M1= 2.263 A1= 0.017
STANDARD ERROR: 0.0186786
CORR. COEFFICIENT: 0.999970

RUN	DISTANCE	TIME	COUNTS	V,FT/SEC	R,REV/SEC	* LOW	EFF,REV/FT	HIGH *	CV,COMP.VEL.	CD,CALC.DIFF.
1	30.87	310.89	10.0	0.099	0.032	*0.836	0.324	0.943	0.090	-0.010
2	32.76	329.78	10.0	0.099	0.030	*0.836	0.305	0.943	0.086	-0.014
3	27.14	170.07	10.0	0.160	0.059	*0.932	0.368	0.997	0.150	-0.010
4	27.60	172.73	10.0	0.160	0.058	*0.932	0.362	0.997	0.148	-0.012
5	25.03	97.50	10.0	0.257	0.103	*0.965	0.400	1.014	0.249	-0.008
6	25.25	98.23	10.0	0.257	0.102	*0.965	0.396	1.014	0.247	-0.010
7	46.97	93.90	20.0	0.500	0.213	*0.996	0.426	1.033	0.499	-0.001
8	46.72	93.53	20.0	0.500	0.214	*0.996	0.428	1.033	0.501	0.001
9	45.95	60.07	20.0	0.765	0.333	*1.007	0.435	1.038	0.770	0.005
10	45.92	60.73	20.0	0.756	0.329	*1.007	0.436	1.038	0.762	0.006
11	92.38	61.62	40.0	1.499	0.649	*1.012	0.433	1.042	1.486	-0.013
12	92.35	62.10	40.0	1.487	0.644	*1.012	0.433	1.042	1.475	-0.012
13	90.73	40.92	40.0	2.217	0.978	0.000	0.441	0.836	2.229	0.012
14	90.42	40.94	40.0	2.209	0.977	0.000	0.442	0.836	2.228	0.019
15	90.35	30.25	40.0	2.987	1.322	0.000	0.443	0.932	3.009	0.023
16	90.53	30.30	40.0	2.988	1.320	0.000	0.442	0.932	3.004	0.017
17	90.24	18.04	40.0	5.002	2.217	0.000	0.443	0.965	5.035	0.033
18	90.23	18.04	40.0	5.002	2.217	0.000	0.443	0.965	5.035	0.033
19	91.26	11.41	40.0	7.998	3.506	0.000	0.438	0.996	7.951	-0.048
20	90.86	11.35	40.0	8.005	3.524	0.000	0.440	0.996	7.993	-0.013
									TOTAL DIFFERENCE=	0.000

CAN ICE CURRENT METER NO. 6-288
DATE RATED: 03-18-86
CONDITIONS: ASRECD
SUSPENSION: ICE ROD
MINIMUM VELOCITY: 0.099
MAXIMUM VELOCITY: 8.005
EQUATION COEFFICIENTS: M1= 2.242 A1= 0.027
M2= 2.312 A2= -0.123
R,REV/SEC AT BREAKPOINT: 2.150
VEL,FT/SEC AT BREAKPOINT: 4.846
STANDARD ERROR: 0.0087769

RUN	DISTANCE	TIME	COUNTS	V,FT/SEC	R,REV/SEC	* LOW	EFF,REV/FT	HIGH *	CV,COMP.VEL.	CD,CALC.DIFF
1	30.87	310.89	10.0	0.099	0.032		0.324		0.099	0.000
2	32.76	329.78	10.0	0.099	0.030		0.305		0.095	0.004
3	27.14	170.07	10.0	0.160	0.059		0.368		0.159	0.001
4	27.60	172.73	10.0	0.160	0.058		0.362		0.157	0.003
5	25.03	97.50	10.0	0.257	0.103		0.400		0.257	0.000
6	25.25	98.23	10.0	0.257	0.102		0.396		0.255	0.002
7	46.97	93.90	20.0	0.500	0.213		0.426		0.505	-0.004
8	46.72	93.53	20.0	0.500	0.214		0.428		0.507	-0.007
9	45.95	60.07	20.0	0.765	0.333		0.435		0.773	-0.009
10	45.92	60.73	20.0	0.756	0.329		0.436		0.765	-0.009
11	92.38	61.62	40.0	1.499	0.649		0.433		1.482	0.017
12	92.35	62.10	40.0	1.487	0.644		0.433		1.471	0.016
13	90.73	40.92	40.0	2.217	0.978		0.441		2.218	-0.001
14	90.42	40.94	40.0	2.209	0.977		0.442		2.217	-0.009
15	90.35	30.25	40.0	2.987	1.322		0.443		2.991	-0.004
16	90.53	30.30	40.0	2.988	1.320		0.442		2.986	0.001
17	90.24	18.04	40.0	5.002	2.217		0.443		5.002	0.000
18	90.23	18.04	40.0	5.002	2.217		0.443		5.002	0.000
19	91.26	11.41	40.0	7.998	3.506		0.438		7.980	0.018
20	90.86	11.35	40.0	8.005	3.524		0.440		8.023	-0.018
									TOTAL DIFFERENCE=	0.000

3 PTS. IN LOWER LINE; 7 PTS. IN UPPER LINE	M1= 2.220	A1= 0.030	M2= 2.268	A2= 0.006	STANDARD ERROR= 0.0166692
4 PTS. IN LOWER LINE; 6 PTS. IN UPPER LINE	M1= 2.197	A1= 0.031	M2= 2.269	A2= 0.002	STANDARD ERROR= 0.0163503
5 PTS. IN LOWER LINE; 5 PTS. IN UPPER LINE	M1= 2.202	A1= 0.031	M2= 2.271	A2=-0.002	STANDARD ERROR= 0.0162615
6 PTS. IN LOWER LINE; 4 PTS. IN UPPER LINE	M1= 2.261	A1= 0.024	M2= 2.281	A2=-0.028	STANDARD ERROR= 0.0174368
7 PTS. IN LOWER LINE; 3 PTS. IN UPPER LINE	M1= 2.244	A1= 0.027	M2= 2.288	A2=-0.048	STANDARD ERROR= 0.0115957
8 PTS. IN LOWER LINE; 2 PTS. IN UPPER LINE	M1= 2.242	A1= 0.027	M2= 2.312	A2=-0.123	STANDARD ERROR= 0.0087769
10 PTS. IN LOWER LINE; 0 PTS. IN UPPER LINE	M1= 2.263	A1= 0.017	M2= 0.000	A2= 0.000	STANDARD ERROR= 0.0186786

CAN ICE CURRENT METER NO. 6-288
DATE RATED: 03-20-86
CONDITIONS: ASRECD
SUSPENSION: CABLE
MINIMUM VELOCITY: 0.098
MAXIMUM VELOCITY: 8.002
EQUATION COEFFICIENTS: M1= 2.355 A1=-0.004
STANDARD ERROR: 0.0581464
CORR. COEFFICIENT: 0.999717

RUN	DISTANCE	TIME	COUNTS	V,FT/SEC	R,REV/SEC	* LOW	EFF,REV/FT	HIGH *	CV,COMP.VEL.	CD,CALC.DIFF
1	34.13	346.95	10.0	0.098	0.029	*0.836	0.293	0.943	0.064	-0.035
2	33.81	343.44	10.0	0.098	0.029	*0.836	0.296	0.943	0.065	-0.034
3	27.21	172.24	10.0	0.158	0.058	*0.932	0.368	0.997	0.133	-0.025
4	27.50	173.54	10.0	0.158	0.058	*0.932	0.364	0.997	0.132	-0.027
5	26.50	100.56	10.0	0.264	0.099	*0.965	0.377	1.014	0.230	-0.033
6	25.72	102.71	10.0	0.250	0.097	*0.965	0.389	1.014	0.225	-0.025
7	48.45	95.55	20.0	0.507	0.209	*0.996	0.413	1.033	0.489	-0.018
8	48.55	97.08	20.0	0.500	0.206	*0.996	0.412	1.033	0.481	-0.019
9	47.16	62.18	20.0	0.758	0.322	*1.007	0.424	1.038	0.753	-0.005
10	47.02	62.76	20.0	0.749	0.319	*1.007	0.425	1.038	0.746	-0.003
11	93.79	62.94	40.0	1.490	0.636	*1.012	0.426	1.042	1.492	0.002
12	93.61	63.36	40.0	1.477	0.631	*1.012	0.427	1.042	1.482	0.005
13	93.00	42.00	40.0	2.214	0.952	0.000	0.430	0.836	2.233	0.024
14	92.89	42.10	40.0	2.206	0.950	0.000	0.431	0.836	2.233	0.027
15	91.58	30.51	40.0	3.002	1.311	0.000	0.437	0.932	3.083	0.081
16	91.53	30.61	40.0	2.990	1.307	0.000	0.437	0.932	3.073	0.083
17	92.13	18.42	40.0	5.002	2.172	0.000	0.434	0.965	5.109	0.107
18	92.13	18.44	40.0	4.996	2.169	0.000	0.434	0.965	5.104	0.107
19	95.14	11.89	40.0	8.002	3.364	0.000	0.420	0.996	7.917	-0.084
20	95.67	11.96	40.0	7.999	3.344	0.000	0.418	0.996	7.871	-0.128

TOTAL DIFFERENCE= 0.000

CAN ICE CURRENT METER NO. 6-288
DATE RATED: 03-20-86
CONDITIONS: ASRECD
SUSPENSION: CABLE
MINIMUM VELOCITY: 0.098
MAXIMUM VELOCITY: 8.002
EQUATION COEFFICIENTS: M1= 2.275 A1= 0.032
M2= 2.535 A2=-0.502
R, REV/SEC AT BREAKPOINT: 2.056
VEL, FT/SEC AT BREAKPOINT: 4.709
STANDARD ERROR: 0.0108201

RUN	DISTANCE	TIME	COUNTS	V,FT/SEC	R,REV/SEC	* LOW	EFF,REV/FT	HIGH *	CV,COMP.VEL.	CD,CALC.DIFF.
1	34.13	346.95	10.0	0.098	0.029		0.293		0.098	0.001
2	33.81	343.44	10.0	0.098	0.029		0.296		0.098	0.000
3	27.21	172.24	10.0	0.158	0.058		0.368		0.164	-0.006
4	27.50	173.54	10.0	0.158	0.058		0.364		0.163	-0.005
5	26.50	100.56	10.0	0.264	0.099		0.377		0.258	0.005
6	25.72	102.71	10.0	0.250	0.097		0.389		0.254	-0.003
7	48.45	95.55	20.0	0.507	0.209		0.413		0.508	-0.001
8	48.55	97.08	20.0	0.500	0.206		0.412		0.501	-0.001
9	47.16	62.18	20.0	0.758	0.322		0.424		0.764	-0.005
10	47.02	62.76	20.0	0.749	0.319		0.425		0.757	-0.008
11	93.79	62.94	40.0	1.490	0.636		0.426		1.478	0.012
12	93.61	63.36	40.0	1.477	0.631		0.427		1.468	0.009
13	93.00	42.00	40.0	2.214	0.952		0.430		2.199	0.016
14	92.89	42.10	40.0	2.206	0.950		0.431		2.193	0.013
15	91.58	30.51	40.0	3.002	1.311		0.437		3.015	-0.013
16	91.53	30.61	40.0	2.990	1.307		0.437		3.005	-0.015
17	92.13	18.42	40.0	5.002	2.172		0.434		5.002	0.000
18	92.13	18.44	40.0	4.996	2.169		0.434		4.996	0.000
19	95.14	11.89	40.0	8.002	3.364		0.420		8.025	-0.023
20	95.67	11.96	40.0	7.999	3.344		0.418		7.975	0.024

TOTAL DIFFERENCE= 0.000

3 PTS. IN LOWER LINE; 7 PTS. IN UPPER LINE	M1= 2.295	A1= 0.030	M2= 2.369	A2=-0.035	STANDARD ERROR=	0.0501248
4 PTS. IN LOWER LINE; 6 PTS. IN UPPER LINE	M1= 2.280	A1= 0.030	M2= 2.378	A2=-0.056	STANDARD ERROR=	0.0469193
5 PTS. IN LOWER LINE; 5 PTS. IN UPPER LINE	M1= 2.260	A1= 0.032	M2= 2.392	A2=-0.089	STANDARD ERROR=	0.0432679
6 PTS. IN LOWER LINE; 4 PTS. IN UPPER LINE	M1= 2.292	A1= 0.028	M2= 2.414	A2=-0.146	STANDARD ERROR=	0.0360085
7 PTS. IN LOWER LINE; 3 PTS. IN UPPER LINE	M1= 2.294	A1= 0.028	M2= 2.452	A2=-0.253	STANDARD ERROR=	0.0273707
8 PTS. IN LOWER LINE; 2 PTS. IN UPPER LINE	M1= 2.275	A1= 0.032	M2= 2.535	A2=-0.502	STANDARD ERROR=	0.0108201
10 PTS. IN LOWER LINE; 0 PTS. IN UPPER LINE	M1= 2.355	A1=-0.004	M2= 0.000	A2= 0.000	STANDARD ERROR=	0.0581464

CALIBRATION DATA FOR CURRENT METER # 6-288, FIELD ROD SUSPENSION

SEPTEMBER 18,1986

RUN NO.:	VELOCITY (CM/SEC)	TIME (SEC)	REVS	REVS/SEC	REV/METRE
1	10.09	148.54	20	0.1346439	1.3344288
2	14.97	98.70	20	0.2026342	1.3536022
3	20.05	73.40	20	0.2724796	1.3590003
4	25.09	55.65	20	0.3593880	1.4323995
5	30.01	46.72	20	0.4280822	1.4264652
6	35.08	79.82	40	0.5005005	1.4268337
7	40.19	59.81	40	0.5721642	1.4236482
8	45.14	51.64	40	0.6489293	1.4375825
9	50.14	55.12	40	0.7256894	1.4473263
10	55.14	50.46	40	0.7927071	1.4376262
11	60.12	46.04	40	0.8688097	1.4451260
12	70.74	58.80	60	1.0204082	1.4424768
13	80.43	51.41	80	1.1670881	1.4510607
14	90.54	45.83	60	1.3091861	1.4459754
15	100.38	41.37	60	1.4503263	1.4448359
16	120.01	57.65	100	1.7346054	1.4453840
17	149.61	46.20	100	2.1645022	1.4467630
18	181.05	38.12	100	2.6232948	1.4488338
19	210.56	32.86	100	3.0432136	1.4451580
20	250.33	27.55	100	3.6297641	1.4499916

EQUATION: STANDARD ESTIMATE OF ERROR:

V= 0.6082N + 0.0060 M/S 0.0030 M/S

2.2578N + 0.0197 FT/SEC 0.0098 FT/SEC

COMPOSITE RATING EQUATIONS: STANDARD ESTIMATE OF ERROR:

N < 0.810 V= 0.6783N + 0.0108 M/S 0.0027 M/S

2.2286N + 0.0358 FT/SEC 0.0088 FT/SEC

0.810 ≤ N V= 0.6888N + 0.0024 M/S 0.0023 M/S

2.2631N + 0.0078 FT/SEC 0.0075 FT/SEC

LOW SPEED CALIBRATION DATA CURRENT METER # 6-288, FIELD ROD SUSPENSION

SEPTEMBER 18,1986

RUN NO.:	VELOCITY (CM/SEC)	TIME (SEC)	REVS	REVS/SEC	REV/METRE
1	3.02	273.70	5	0.0182682	0.6048065
2	4.02	115.28	5	0.0433727	1.0788216
3	6.00	72.55	5	0.0689180	1.1486331
4	8.02	103.05	10	0.0970403	1.2099785
5	10.02	77.70	10	0.1287001	1.2844324
6	12.01	59.76	10	0.1673360	1.3933057
7	14.12	102.74	20	0.1946661	1.3786554
8	16.09	87.76	20	0.2278943	1.4163720
9	18.12	77.43	20	0.2582976	1.4254846
10	20.24	72.04	20	0.2776235	1.3716578
11	22.15	63.43	20	0.3153082	1.4235134
12	24.09	58.42	20	0.3423485	1.4211228
13	26.08	53.20	20	0.3759386	1.4414872
14	28.13	49.60	20	0.4032258	1.4334369
15	30.23	45.98	20	0.4349717	1.4388744
16	32.36	86.45	40	0.4626952	1.4298368
17	34.13	81.35	40	0.4917025	1.4406754
18	36.11	77.31	40	0.5173975	1.4328371
19	38.15	73.89	40	0.5413452	1.4189815
20	40.19	69.62	40	0.5745475	1.4295784
21	42.25	66.20	40	0.6042296	1.4301282
22	44.26	62.80	40	0.6369427	1.4390933
23	46.27	60.15	40	0.6650042	1.4372253
24	48.13	57.79	40	0.6921613	1.4381078
25	50.21	55.38	40	0.7222824	1.4385230
26	52.13	53.35	40	0.7497657	1.4382615
27	54.16	51.65	40	0.7744434	1.4298176
28	56.23	49.54	40	0.8074283	1.4359387
29	58.07	48.11	40	0.8314280	1 4317685
30	60.15	46.35	40	0.8629988	1.4347447

EQUATION: STANDARD ESTIMATE OF ERROR:

V= 0.6824N + 0.0094 M/S 0.0033 M/S

2.2388N + 0.0308 FT/SEC 0.0108 FT/SEC

COMPOSITE RATING EQUATIONS: STANDARD ESTIMATE OF ERROR:

N < 0.328 V= 0.6536N + 0.0148 M/S 0.0033 M/S

2.1443N + 0.0486 FT/SEC 0.0108 FT/SEC

0.328 ≤ N V= 0.6957N + 0.0010 M/S 0.0016 M/S

2.2825N + 0.0033 FT/SEC 0.0052 FT/SEC

CALIBRATION DATA FOR CURRENT METER # 6-288, ON WINTER WEIGHT ASSEMBLY

SEPTEMBER 23,1986

RUN NO.:	VELOCITY (CM/SEC)	TIME (SEC)	REVS	REVS/SEC	REV/METRE
1	20.15	69.63	20	0.2872325	1.4254715
2	25.07	55.86	20	0.3573981	1.4256009
3	30.11	46.36	20	0.4314064	1.4327678
4	35.26	78.07	40	0.5123607	1.4530833
5	40.08	68.69	40	0.5823264	1.4529102
6	50.09	54.31	40	0.7365126	1.4703785
7	55.13	48.64	40	0.8058018	1.4616393
8	60.05	45.90	40	0.8714587	1.4512235
9	70.61	58.32	60	1.0288066	1.4570267
10	80.51	51.28	60	1.1698187	1.4530104
11	90.09	46.01	60	1.3040643	1.4475129
12	100.28	41.27	60	1.4538406	1.4497812
13	120.22	57.71	100	1.7328019	1.4413591
14	150.32	46.34	100	2.1579628	1.4355784
15	180.60	38.68	100	2.5846472	1.4311446
16	210.36	33.51	100	2.9841838	1.4186080
17	250.26	28.44	100	3.5161744	1.4050086

EQUATION: STANDARD ESTIMATE OF ERROR:

V= 0.7090N - 0.0160 M/S 0.0113 M/S

2.3261N - 0.0525 FT/SEC 0.0371 FT/SEC

COMPOSITE RATING EQUATIONS: STANDARD ESTIMATE OF ERROR:

N < 0.738 V= 0.6648N + 0.0125 M/S 0.0016 M/S

2.1811N + 0.0410 FT/SEC 0.0052 FT/SEC

0.738 $\leq$ N $\leq$ 2.483 V= 0.7028N - 0.0156 M/S 0.0024 M/S

2.3057N - 0.0512 FT/SEC 0.0079 FT/SEC

2.483 $\leq$ N V= 0.7479N - 0.1276 M/S 0.0010 M/S

2.4537N - 0.4186 FT/SEC 0.0033 FT/SEC

LOW SPEED CALIBRATION DATA CURRENT METER # 6-288, ON WINTER WEIGHT ASSEMBLY

SEPTEMBER 23,1986

RUN NO.:	VELOCITY (CM/SEC)	TIME (SEC)	REVS	REVS/SEC	REV/METRE
1	3.02	92.71	3	0.0323590	1.0714880
2	4.01	59.48	3	0.0504371	1.2577836
3	6.02	130.40	10	0.0766871	1.2738724
4	8.07	95.21	10	0.1050310	1.3014882
5	10.12	76.28	10	0.1310960	1.2954146
6	12.09	64.04	10	0.1561524	1.2915832
7	14.05	107.43	20	0.1861677	1.3250373
8	16.05	91.46	20	0.2186748	1.3624600
9	18.01	79.76	20	0.2507523	1.3922946
10	20.11	71.75	20	0.2787456	1.3861048
11	22.16	65.09	20	0.3072669	1.3865833
12	24.16	59.02	20	0.3388682	1.4026001
13	26.12	54.24	20	0.3687316	1.4116829
14	28.09	50.66	20	0.3947868	1.4054425
15	30.09	47.67	20	0.4195511	1.3943206
16	32.07	88.16	40	0.4537205	1.4147818
17	34.07	83 86	40	0.4769855	1.4000160
18	36.10	78.88	40	0.5070894	1.4047075
19	38.09	74.80	40	0.5347594	1.4039364
20	40.07	70.09	40	0.5706848	1.4242446
21	42.07	66.75	40	0.5992509	1.4244139
22	44.05	62.59	40	0.6390797	1.4508053
23	45.80	60.60	40	0.6600660	1.4380523
24	48.02	57.61	40	0.6943239	1.4459057
25	50.12	54.97	40	0.7276686	1.4518548
26	52.12	53.04	40	0.7541478	1.4469452
27	54.03	51.17	40	0.7817080	1.4468037
28	56.17	48.88	40	0.8183306	1.4568820
29	58.13	47.49	40	0.8422826	1.4489637
30	60.09	45.99	40	0.8697543	1.4474194

EQUATION: STANDARD ESTIMATE OF ERROR:

V= 0.6776N + 0.0119 M/S 0.0033 M/S

2.2231N + 0.0390 FT/SEC 0.0108 FT/SEC

COMPOSITE RATING EQUATIONS: STANDARD ESTIMATE OF ERROR:

N < 0.496 V= 0.6825N + 0.0084 M/S 0.0022 M/S

2.2723N + 0.0276 FT/SEC 0.0072 FT/SEC

0.496 ≤ N V= 0.6567N + 0.0262 M/S 0.0027 M/S

2.1545N + 0.0860 FT/SEC 0.0088 FT/SEC

Calibration Data for USGS Vane Ice Meter I-39

Equations V=2.310R + ~~0.011~~ (.994) 2.222R + 0.044
Actual Rating Limits 0.10 to 5.0 Feet/Sesond
Rated 0.10 to 1.0 on 6-12-81 and 1.0 to 5.0 on

SEC	REVOLUTIONS 3	5	7	10	15	20	SEC
40	.184	.300	.415	.589	.877	1.15	40
41	.180	.293	.405	.574	.855	1.13	41
42	.176	.286	.395	.561	.835	1.10	42
43	.172	.280	.387	.548	.817	1.08	43
44	.168	.273	.378	.536	.799	1.05	44
45	.165	.268	.370	.524	.781	1.03	45
46	.162	.262	.363	.513	.764	1.01	46
47	.159	.257	.355	.502	.749	.994	47
48	.155	.252	.348	.492	.733	.974	48
49	.152	.247	.341	.482	.719	.954	49
50	.150	.242	.334	.473	.704	.935	50
51	.147	.237	.328	.464	.690	.917	51
52	.144	.233	.322	.455	.677	.899	52
53	.142	.229	.316	.447	.665	.883	53
54	.139	.225	.310	.439	.653	.867	54
55	.137	.221	.305	.431	.641	.851	55
56	.135	.217	.300	.423	.630	.836	56
57	.133	.214	.295	.416	.619	.822	57
58	.130	.210	.290	.409	.608	.808	58
59	.128	.207	.285	.403	.598	.794	59
60	.126	.203	.280	.396	.589	.781	60
61	.125	.200	.275	.390	.579	.768	61
62	.123	.197	.272	.384	.570	.756	62
63	.121	.194	.269	.378	.561	.744	63
64	.119	.191	.264	.372	.552	.733	64
65	.118	.189	.260	.366	.544	.722	65
66	.116	.186	.255	.361	.535	.711	66
67	.114	.183	.252	.356	.529	.701	67
68	.113	.181	.249	.351	.521	.690	68
69	.111	.178	.245	.346	.513	.681	69
70	.110	.176	.242	.341	.505	.671	70

9-21-76 Ice #32

SEC	SEC 25	30	40	SEC 50	60	80	100	HE.
40	1.43	1.71	2.27	40	40	2.82	3.38	4.49	5.60
41	1.40	1.67	2.21	41	41	2.75	3.30	4.38	5.46
42	1.37	1.63	2.16	42	42	2.69	3.22	4.28	5.33
43	1.34	1.59	2.11	43	43	2.63	3.14	4.18	5.21
44	1.31	1.56	2.06	44	44	2.57	3.07	4.08	5.09
45	1.28	1.53	2.02	45	45	2.51	3.01	3.99	4.98
46	1.25	1.49	1.98	46	46	2.46	2.94	3.91	4.87
47	1.23	1.46	1.94	47	47	2.41	2.88	3.83	4.77
48	1.20	1.43	1.90	48	48	2.36	2.82	3.75	4.67
49	1.18	1.40	1.86	49	49	2.31	2.76	3.67	4.58
50	1.15	1.38	1.82	50	50	2.27	2.71	3.60	4.49
51	1.13	1.35	1.79	51	51	2.22	2.66	3.53	4.40
52	1.11	1.33	1.75	52	52	2.18	2.61	3.46	4.32
53	1.09	1.30	1.72	53	53	2.14	2.56	3.40	4.24
54	1.07	1.28	1.69	54	54	2.10	2.51	3.34	4.16
55	1.05	1.26	1.66	55	55	2.06	2.47	3.28	4.08
56	1.04	1.23	1.63	56	56	2.03	2.42	3.22	4.01
57	1.02	1.21	1.60	57	57	1.99	2.38	3.16	3.94
58	1.00	1.19	1.58	58	58	1.96	2.34	3.11	3.88
59	.990	1.17	1.55	59	59	1.93	2.30	3.06	3.81
60	.974	1.15	1.53	60	60	1.90	2.27	3.01	3.75
61	.958	1.14	1.50	61	61	1.87	2.23	2.96	3.69
62	.942	1.12	1.48	62	62	1.84	2.19	2.91	3.63
63	.929	1.10	1.45	63	63	1.81	2.16	2.87	3.57
64	.913	1.09	1.43	64	64	1.78	2.13	2.82	3.52
65	.899	1.07	1.41	65	65	1.75	2.10	2.78	3.46
66	.886	1.05	1.39	66	66	1.73	2.06	2.74	3.41
67	.873	1.04	1.37	67	67	1.70	2.03	2.70	3.36
68	.860	1.02	1.35	68	69	1.68	2.00	2.66	3.31
69	.848	1.01	1.33	69	69	1.65	1.98	2.62	3.26
70	.836	.996	1.31	70	70	1.63	1.95	2.58	3.22

CALIBRATION DATA FOR METER # ICE 39-ROD SUSPENDED

RUN NO:	VELOCITY (CM/SEC)	REV/SEC	REV/METRE	EQUATIONS
1	2.01	0.0175	0.8684	
2	4.01	0.0576	1.4357	
3	8.12	0.1154	1.4218	
4	9.07	0.1222	1.3469	
5	10.09	0.1335	1.3234	V=0.6968N + 0.0144 M/S
6	12.06	0.1577	1.3075	
7	14.08	0.1909	1.3562	2.2859N + 0.0473 FT/SEC
8	16.01	0.2193	1.3696	
9	18.08	0.2454	1.3575	
10	20.08	0.2686	1.3378	STANDARD ESTIMATE OF ERROR:
11	25.02	0.3443	1.3761	
12	30.17	0.4085	1.3540	0.008 M/S
13	35.14	0.4740	1.3489	
14	40.10	0.5441	1.3570	0.027 FT/SEC
15	45.14	0.6197	1.3728	
16	50.00	0.6804	1.3608	
17	55.12	0.7603	1.3794	
18	59.99	0.8246	1.3745	
19	70.89	0.9766	1.3776	
20	80.98	1.1299	1.3953	
21	90.99	1.2698	1.3956	
22	100.81	1.4138	1.4024	
23	120.31	1.6975	1.4109	
24	135.82	1.9186	1.4126	
25	150.67	2.1404	1.4216	
26	165.37	2.3529	1.4228	
27	180.82	2.5714	1.4221	
28	195.04	2.7847	1.4278	
29	210.37	3.0120	1.4318	
30	230.62	3.3014	1.4315	
31	250.23	3.5842	1.4324	

COMPOSITE RATING:	EQUATIONS:	STANDARD ESTIMATE OF ERROR:
N < 0.857	V=0.7263N + 0.0029 M/S	0.003 M/S
	2.3829N + 0.0094 FT/SEC	0.011 FT/SEC
0.857 ≤ N	V=0.6878N + 0.0359 M/S	0.002 M/S
	2.2565N + 0.1176 FT/SEC	0.007 FT/SEC

Where V= velocity
N= rev/sec
February,1986

FLUCTUATING VELOCITIES

CALIBRATION DATA FOR METER # ICE 39

SUSPENSION:ROD

RUN NO:	AVERAGE VELOCITY (CM/SEC)	REV/SEC	REV/METRE	EQUATIONS
1	18.36	0.2601	1.4166	
2	20.15	0.2803	1.3911	
3	22.12	0.3060	1.3836	
4	24.28	0.3279	1.3504	
5	26.18	0.3589	1.3709	V=0.6886N + 0.0097M/S
6	27.99	0.4027	1.4387	2.2592N + 0.0318FT/SEC
7	30.12	0.4208	1.3969	
8	31.99	0.4506	1.4087	STANDARD ESTIMATE OF ERROR:
9	34.52	0.4917	1.4243	
10	36.11	0.5076	1.4057	0.005 M/S 0.015 FT/SEC

Where V= Velocity
N= Rev/Sec
February,1986

FRAZ ICE CURRENT METER NO. 39
DATE RATED: 03-20-86
CONDITIONS: ASRECD
SUSPENSION: ROD
MINIMUM VELOCITY: 0.099
MAXIMUM VELOCITY: 8.013
EQUATION COEFFICIENTS: M1= 2.331 A1= 0.016
M2= 2.158 A2= 0.212
R, REV/SEC AT BREAKPOINT: 1.128
VEL, FT/SEC AT BREAKPOINT: 2.645
STANDARD ERROR: 0.0094997

RUN	DISTANCE	TIME	COUNTS	V,FT/SEC	R,REV/SEC	* LOW	EFF,REV/FT	HIGH *	CV,COMP.VEL.	CD,CALC.DIFF.
1	31.56	320.26	10.0	0.099	0.031		0.317		0.089	0.010
2	29.13	295.16	10.0	0.099	0.034		0.343		0.095	0.004
3	25.39	160.75	10.0	0.158	0.062		0.394		0.161	-0.003
4	25.09	158.82	10.0	0.158	0.063		0.399		0.163	-0.005
5	24.59	93.36	10.0	0.263	0.107		0.407		0.266	-0.002
6	23.83	94.47	10.0	0.252	0.106		0.420		0.263	-0.010
7	47.42	93.46	20.0	0.507	0.214		0.422		0.515	-0.007
8	47.85	95.60	20.0	0.501	0.209		0.418		0.504	-0.003
9	47.91	63.19	20.0	0.758	0.317		0.417		0.754	0.004
10	47.78	63.78	20.0	0.749	0.314		0.419		0.747	0.002
11	95.15	63.86	40.0	1.490	0.626		0.420		1.476	0.014
12	94.97	64.28	40.0	1.477	0.622		0.421		1.467	0.011
13	93.48	42.23	40.0	2.214	0.947		0.428		2.224	-0.010
14	93.74	42.49	40.0	2.206	0.941		0.427		2.211	-0.004
15	92.98	30.97	40.0	3.002	1.292		0.430		2.998	0.004
16	93.33	31.21	40.0	2.990	1.282		0.429		2.977	0.013
17	89.63	17.92	40.0	5.002	2.232		0.446		5.028	-0.026
18	90.07	18.02	40.0	4.998	2.220		0.444		5.001	-0.003
19	88.65	11.07	40.0	8.008	3.613		0.451		8.008	0.000
20	88.78	11.08	40.0	8.013	3.610		0.451		8.001	0.012
									TOTAL DIFFERENCE=	0.000

3 PTS. IN LOWER LINE; 7 PTS. IN UPPER LINE	M1= 2.162	A1= 0.026	M2= 2.201	A2= 0.095	STANDARD ERROR=	0.0526340
4 PTS. IN LOWER LINE; 6 PTS. IN UPPER LINE	M1= 2.281	A1= 0.019	M2= 2.191	A2= 0.119	STANDARD ERROR=	0.0272617
5 PTS. IN LOWER LINE; 5 PTS. IN UPPER LINE	M1= 2.331	A1= 0.015	M2= 2.177	A2= 0.155	STANDARD ERROR=	0.0149999
6 PTS. IN LOWER LINE; 4 PTS. IN UPPER LINE	M1= 2.353	A1= 0.012	M2= 2.167	A2= 0.182	STANDARD ERROR=	0.0120875
7 PTS. IN LOWER LINE; 3 PTS. IN UPPER LINE	M1= 2.331	A1= 0.016	M2= 2.158	A2= 0.212	STANDARD ERROR=	0.0094997
8 PTS. IN LOWER LINE; 2 PTS. IN UPPER LINE	M1= 2.321	A1= 0.018	M2= 2.172	A2= 0.165	STANDARD ERROR=	0.0142238
10 PTS. IN LOWER LINE; 0 PTS. IN UPPER LINE	M1= 2.216	A1= 0.059	M2= 0.000	A2= 0.000	STANDARD ERROR=	0.0449141

FRAZ ICE CURRENT METER NO. 39
DATE RATED: 03-20-86
CONDITIONS: ASRECD
SUSPENSION: ROD
MINIMUM VELOCITY: 0.099
MAXIMUM VELOCITY: 8.013
EQUATION COEFFICIENTS: M1= 2.216 A1= 0.059
STANDARD ERROR: 0.0449141
CORR. COEFFICIENT: 0.999831

RUN	DISTANCE	TIME	COUNTS	V,FT/SEC	R,REV/SEC	* LOW	EFF,REV/FT	HIGH *	CV,COMP.VEL.	CD,CALC.DIF
1	31.56	320.26	10.0	0.099	0.031	*0.836	0.317	0.943	0.128	0.030
2	29.13	295.16	10.0	0.099	0.034	*0.836	0.343	0.943	0.134	0.036
3	25.39	160.75	10.0	0.158	0.062	*0.932	0.394	0.997	0.197	0.039
4	25.09	158.82	10.0	0.158	0.063	*0.932	0.399	0.997	0.199	0.041
5	24.59	93.36	10.0	0.263	0.107	*0.965	0.407	1.014	0.297	0.033
6	23.83	94.47	10.0	0.252	0.106	*0.965	0.420	1.014	0.294	0.042
7	47.42	93.46	20.0	0.507	0.214	*0.996	0.422	1.033	0.534	0.026
8	47.85	95.60	20.0	0.501	0.209	*0.996	0.418	1.033	0.523	0.022
9	47.91	63.19	20.0	0.758	0.317	*1.007	0.417	1.038	0.761	0.003
10	47.78	63.78	20.0	0.749	0.314	*1.007	0.419	1.038	0.754	0.005
11	95.15	63.86	40.0	1.490	0.626	*1.012	0.420	1.042	1.447	-0.043
12	94.97	64.28	40.0	1.477	0.622	*1.012	0.421	1.042	1.438	-0.039
13	93.48	42.23	40.0	2.214	0.947	0.000	0.428	0.836	2.158	-0.055
14	93.74	42.49	40.0	2.206	0.941	0.000	0.427	0.836	2.146	-0.061
15	92.98	30.97	40.0	3.002	1.292	0.000	0.430	0.932	2.922	-0.081
16	93.33	31.21	40.0	2.990	1.282	0.000	0.429	0.932	2.900	-0.091
17	89.63	17.92	40.0	5.002	2.232	0.000	0.446	0.965	5.006	0.005
18	90.07	18.02	40.0	4.998	2.220	0.000	0.444	0.965	4.979	-0.020
19	88.65	11.07	40.0	8.008	3.613	0.000	0.451	0.996	8.067	0.059
20	88.78	11.08	40.0	8.013	3.610	0.000	0.451	0.996	8.060	0.048
									TOTAL DIFFERENCE=	0.000

CALIBRATION DATA FOR CURRENT METER # ICE 39, ROD SUSPENSION

SEPTEMBER 18,1986

RUN NO.:	VELOCITY (CM/SEC)	TIME (SEC)	REVS	REVS/SEC	REV/METRE
1	10.09	145.79	20	0.1371836	1.3595998
2	14.97	98.77	20	0.2024806	1.3526429
3	20.05	74.02	20	0.2701872	1.3476172
4	25.09	57.31	20	0.3489782	1.3909097
5	30.01	48.28	20	0.4142502	1.3803739
6	35.09	82.88	40	0.4826255	1.3753932
7	40.19	71.83	40	0.5568704	1.3855944
8	45.14	64.08	40	0.6242197	1.3828527
9	50.14	57.23	40	0.6989341	1.3939651
10	55.14	52.23	40	0.7658434	1.3889071
11	60.12	47.49	40	0.8422826	1.4010023
12	70.74	60.79	60	0.9870044	1.3952565
13	80.43	53.15	60	1.1288805	1.4035565
14	90.54	47.16	60	1.2722646	1.4051962
15	100.38	42.95	60	1.3969732	1.3916848
16	120.01	59.45	100	1.6820858	1.4016214
17	149.61	46.90	100	2.1321962	1.4251695
18	181.05	38.51	100	2.5867281	1.4342602
19	210.58	32.82	100	3.0469226	1.4469193
20	250.33	27.35	100	3.6563071	1.4605948

EQUATION:		STANDARD ESTIMATE OF ERROR:
V=	0.6863N + 0.0223 M/S	0.0127 M/S
	2.2516N + 0.0732 FT/SEC	0.0417 FT/SEC

COMPOSITE RATING EQUATIONS:		STANDARD ESTIMATE OF ERROR:
N < 1.725 V=	0.7103N + 0.0058 M/S	0.0027 M/S
	2.3304N + 0.0190 FT/SEC	0.0089 FT/SEC
1.725 ≤ N V=	0.6601N + 0.0924 M/S	0.0046 M/S
	2.1657N + 0.3031 FT/SEC	0.0151 FT/SEC

LOW SPEED CALIBRATION DATA CURRENT METER # ICE 38, ROD SUSPENSION

SEPTEMBER 18,1986

RUN NO.:	VELOCITY (CM/SEC)	TIME (SEC)	REVS	REVS/SEC	REV/METRE
1	2.54	178.23	5	0.0278971	1.0983116
2	4.20	112.34	5	0.0445077	1.1071578
3	6.00	68.88	5	0.0725785	1.2096579
4	8.02	97.63	10	0.1024275	1.2771513
5	10.02	76.07	10	0.1314579	1.3118548
6	12.01	58.88	10	0.1698370	1.4141295
7	14.12	102.46	20	0.1951981	1.3824230
8	16.09	87.60	20	0.2283105	1.4189590
9	18.12	78.87	20	0.2504068	1.3819366
10	20.24	72.66	20	0.2752546	1.3598536
11	24.08	59.90	20	0.3338898	1.3860100
12	26.08	54.75	20	0.3652968	1.4006779
13	28.13	50.95	20	0.3925417	1.3954558
14	30.23	47.42	20	0.4217630	1.3951802
15	32.36	88.34	40	0.4477278	1.3835840
16	34.13	83.91	40	0.4767012	1.3967220
17	36.11	79.34	40	0.5041593	1.3961764
18	38.15	76.38	40	0.5236973	1.3727321
19	40.19	72.13	40	0.5545543	1.3798315
20	42.25	68.74	40	0.5819028	1.3772848
21	44.26	65.38	40	0.6117143	1.3820929
22	46.27	62.46	40	0.6404099	1.3840715
23	48.13	60.17	40	0.6647831	1.3812240
24	50.21	57.71	40	0.6931208	1.3804437
25	52.13	55.70	40	0.7181329	1.3775808
26	54.16	53.85	40	0.7428041	1.3714894
27	56.23	51.80	40	0.7722008	1.3732897
28	58.07	50.24	40	0.7961783	1.3710665
29	60.15	48.25	40	0.8290155	1.3782470

EQUATION: STANDARD ESTIMATE OF ERROR:

V= 0.7210N + 0.0022 M/S 0.0035 M/S

2.3655N + 0.0072 FT/SEC 0.0115 FT/SEC

COMPOSITE RATING EQUATIONS: STANDARD ESTIMATE OF ERROR:

N < 0.322 V= 0.6884N + 0.0081 M/S 0.0032 M/S

2.2585N + 0.0266 FT/SEC 0.0105 FT/SEC

0.322 ≤ N V= 0.7366N - 0.0074 M/S 0.0017 M/S

2.4166N - 0.0243 FT/SEC 0.0056 FT/SEC